THE TERTIARY VOLCANIC ROCKS
OF THE
TAMAR TROUGH, NORTHERN TASMANIA.

BY

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submitted in fulfilment of the requirements
for the Degree of
Master of Science,
University of Tasmania.

Hobart.

(30/9/68.)

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University, and to the best of my knowledge and belief contains no copy or paraphrase of material previously published or written by another person, except where due reference is made in the text of the thesis.

H. L. Sutherland 23RD September 1968.

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ABSTRACT.

Tertiary volcanic rocks are widespread in the Tamar Trough, a fault structure formed in late Mesozoic or early Tertiary time. The volcanic rocks are predominantly confined lavas, erupted from a number of centres, and fill old channels of the Tamar River System. Eruptions commenced in the Lower Tertiary, following dissection of Palaeocene-Middle Eocene sediments filling the Tamar Trough, became maximal in the Middle Tertiary, and may have continued into the Upper Tertiary.

The volcanic suite ranges from strongly under-saturated lavas of olivine-nephelinite, limburgite and nepheline-basanite, through under-saturated to near-saturated alkali olivine-basalts and tholeiitic olivine-basalt. The field stratigraphy tentatively suggests the following eruptive sequence: olivine-basalts in the lower, middle and south Tamar areas in Upper Eocene-Oligocene(?) time, followed by olivine- nephelinite and nepheline-basanite in the middle Tamar area in Oligocene (?) time, and then widespread effusions of under-saturated olivine-basalts in the middle, upper and south Tamar areas in Middle-Upper (?) Tertiary time. These last include thick lavas of coarse olivine-basalt in which some differentiation took place and in which pegmatitic phases

devdoped. The relationships of olivine-nephelinite, limburgite, and tholeiitic olivine-basalt in the south Tamar area to the eruptive sequence are unknown. The Tamar lavas are similar to those in adjacent areas to the north-west, south-west and north-east, but differ somewhat from those in adjacent areas to the south and east, where tholeiitic olivine-basalts predominate.

The Tamar lavas resemble the Older Volcanic Series of Victoria and the Auckland basalts in New Zealand, in their petrochemistry. The eruptive history of the Tamar lavas appears to differ in some respects from that of the Older Volcanics of Victoria. Chemical variation diagrams show that the Tamar lavas essentially form an alkaline association falling generally along a similar trend to the Hawaiian alkali basalts and to some extent the Black Jack teschenite trend. The alkaline association passes into an olivine-tholeiitic association to the south-east, and the parent magmas of the two associations may have derived from differing degrees of partial melting of mantle pyrolite.

INTRODUCTION.

The volcanic rocks investigated in this study occur within the Tamar Valley and south of the head of the Tamar River. They are associated with the Tamar Trough, a fault structure formed prior to, or early in, the Tertiary (Longman, et.al., 1966). This trough has formed an important locus of Cainozoic drainage in Tasmania and is associated with considerable non-marine sedimentation. The volcanic rocks in general represent confined lavas with little overspilling of the trough margins, and in many cases they preserve the course of the ancestral Tamar at the time of eruption.

Prior to this study, the prevalence of volcanic rocks associated with the Tamar Trough was not fully realised, partly due to the localised nature of previous mapping and partly due to confusion of the coarser grained flows with the Jurassic dolerite bedrock of the area. The general distribution, nature, and relationships of the volcanic rocks have been outlined in a preliminary note (Sutherland, 1966a). The detailed results presented here also include investigations of Tertiary volcanic rocks in adjacent areas for comparison with those of the Tamar Trough. As the precise dating of the Tasmanian Cainozoic volcanic rocks pose many problems, this study has also involved investigations in some critical areas elsewhere in the State, to determine any guiding relationships between petrological types and eruptive age. Such a relationship has been demonstrated in Victoria, but only partly investigated in Tasmania (Edwards, 1950). The results of this aspect are published elsewhere (Sutherland, and Corbett, 1967) and indicate that dating by petrological types cannot be as reliably utilised in Tasmania as in Victoria (see also Sutherland, 1968).

Access to the Tamar Valley area is easy, with both the east and west Tamar areas and the coutry to the south being served by highways with numerous side roads. Much of the area is cultivated, with easy terrain. The author's field mapping commenced in 1963 and was accomplished with aerial photographs on a scale of approximately four inches to the mile. Detailed topographic Lands and Surveys maps became available for the area during the later stages of the study and the geological maps presented here incorporate some control from these maps The author was employed at the Queen Victoria Museum in Launceston during much of this study and collected specimens are held both in this institution and in the Tasmanian Museum, Hobart. Thin section numbers refer to the Tasmanian Museum catalogued collection.

PREVIOUS INVESTIGATIONS AND LITERATURE.

Collections of local rockswere made by Lieut. Col. William Patterson with the establishment of European settlement at Port Dalrymple at the beginning of the nineteenth century. Some of this collection is held at the Queen Victoria Museum and is now only of historical importance.

Many of the early geological studies in the Tamar Valley were in the gold mining district of Beaconsfield and contributed little to the knowledge of the Cainozoic rocks, except in regard to the Tertiary deep lead near Cabbage Tree Hill (Scott, 1930). Most of these studies are reviewed amongst geological observations on the Tamar Valley (Kershaw, 1955, 1958), in the geological mapping of the Beaconsfield square (Green, 1959), and in the later Tasmanian Mines Department reports, e.g. Noldart (1964). Early contributions on the Cainozoic rocks of the area include studies by Johnston (1874, 1875, 1880, 1888), Etheridge (1881), Montgomery (1892), and Twelvetrees (1904). Some of these give observations on the basalts in the Breadalbane and Tamar Heads areas.

Regional mapping of the Launceston district (Carey, 1946), outlined the main features of the Tamar Trough and its geological history. Accurate dating of some of the Tertiary sediments was an important advance in providing some limits for the ages of the Tamar Trough and the associated basalts (Gill and Banks, 1956; Gill, 1962). Several investigations have been made of the Cainozoic sediments at Launceston in regard to foundation conditions (Longman _et.al._ 1966).

Further detailed studies on the Tertiary sediments (E.D. Gill, pers. comm.) are being prepared for publication by G.D. Aitchison (Commonwealth Scientific and Industrial Research Organisation) and E.D. Gill (National Museum of Victoria.) The first petrological studies of the basalts (Edwards, 1950) were limited to only a few scattered samples. In a geomorphological study of the Launceston Tertiary basin, Nicolls (1960) discussed the ages of the basalts in that area and the lateritic surfaces developed on them.

Detailed investigations in a few of the basalt areas in the Tamar Valley have provided some valuable data. Investigations in the Bell Bay area commenced with enquiries as to its suitability as a port (Skeats, 1922; Launceston Marine Board bore logs). Further investigations for industrial foundation sites included soil tests, seismic, and drilling programmes (Polak, 1961; McLaren and Taylor 1961; Matthews, 1966; and Comalco-Bell Bay file reports). Exploratory programmes for a trans-Tamar bridge site by the Tasmanian Mines and Public Works Departments provided geological and sub-surface information on the basalts at Whirlpool Reach (Hughes, 1958, 1959; Tasmanian Department of Public Works, 1957) and at Long Reach (Blake, 1960; Maunsell and Partners, 1959, 1962). The Beauty Point - Kelso area has received attention in connection with wharf and navigational extensions (Launceston Marine Board bore logs) and landslip problems (Blake, 1961; Jennings 1964a, 1964b). Finally, basalt bearing sediments of probably Tertiary age have been revealed in recent Tasmanian Mines Department borings near Perth (Jennings, 1965).

Further investigations, other than the author's study, are being conducted at present in the Tamar Valley and surrounding areas by the Tasmanian Department of Mines Geological Survey as part of the 1" to 1 mile state mapping programme. The Longford Sheet (Blake, 1959) was available prior to the present study, with the Launceston Sheet and explanatory report (Longman et.al., 1964, 1966) appearing more recently. At the time of writing, mapping of the Beaconsfield and Frankford Sheets is proceeding and will complete the coverage of the Tamar Valley area.

PHYSIOGRAPHY.

The Tamar Valley is a broad, drowned, esturine tract over five miles wide, in which the Tamar River rises from the junction of its North and South Esk tributaries at Launceston and flows some 35 miles out to Bass Strait.

The basalt extrusions within the valley have had important physiographic influences. More resistant than the Tertiary sediments, they cap the higher areas. Dissected basalt plateaux reach elevations of 700 feet in the Rosevears area and 600 feet north-west of Hillwood. Lower basalt plateaux, however, such as in the Bell Bay-Georgetown area at about 100 feet elevation, tend to be buried under Upper Cainozoic gravels and sands. In areas where basalt extrusions are absent, as between Hillwood and Native Point and between Dilston and Launceston, the Tertiary sediments in the central part of the valley are eroded to spurs, mostly less than 200 feet in elevation. Above the Tamar's head of erosion at Launceston, the sediments are preserved at higher levels and in the St. Leonards - Breadalbane - White Hills area there are dissected basalt plateau cappings at elevations at about 750 feet, with one small occurrence at about 900 feet.

The basalt extrusions have also influenced the course of the Tamar. The river originally appears to have extended further south through Evandale, prior to diversion from the Tamar Trough by the lava at Breadalbane, west through Hadspen as the South Esk. Potentially imminent capture of the South Esk by Rose Rivulet at Evandale, however, if made, will re-divert the South Esk back into the Tamar Trough. There is possible similar past diversion by the basalt flows in the lower Tamar, west through Beaconsfield and out the valley between West and Badger Head. Later extrusion upstream, however, may have diverted the river back to its original course. In contrast, in the middle reaches of the Tamar the river appears superimposed on the basalt filling its old channel, and these points are discussed later.

Landslips are common in the Tamar Valley and are an important factor in the interpretation of outcrop; heels of slides or inferred slides have been mapped in this investigation. There is concern about active movements above the Tamar's head of erosion at South Launceston (Longman _et. al._,1966) and also at Beaty Point (Blake, 1961; Jennings,1964a), while historic slides have been recorded near Rosevears (Friend,1849). The slips are occasioned by the erosive action of the Tamar drainage system on the Cainozoic beds filling the Tamar Trough. Alternation of more permeable gravelly and sandy horizons and less permeable clay horizons, and the relatively unconsolidated nature of the sediments make valley slopes highly unstable. Slumping soon becomes evident in new artificial cuttings through the sediments. Resistant basalt cappings are wasted by undermining, a process greatly enhanced by certain of their features. It is significant that the basalts are mostly steep valley fillings and that in many places the present course of the Tamar is superimposed over the old buried channel. As a result, the bases of the basalt exposures slope downwards towards the river on both sides of its valley. This, combined with the resultant overhanging of extensive columnar and block jointing in the basalt normal to the base, and with the downward slope of sheet jointing parallel to the base, provides extremely favourable conditions for failure under gravity. Failure takes place both by backward rotational sliding and by forward toppling, and valley sides in these areas have widespread mantles of basalt float. Large and extensive slides show toes with rocks rotated to near vertical positions. Very large blocks occur amongst the talus debris in some localities, and gaps amongst these form cavern systems, extending to depths of over 30 feet. The bushranger Brady is reputed to have exploited these physiographic features, keeping a watchout for troppers from the basalt eminence that bears his name and then eluding them by hiding in the talus caverns. The future development of the Tamar Valley will require an increasing awareness of the widespread instability of much of the valley sides. In this connection may be mentioned the recommendations of restricted building zones at Beauty Point (Jennings, 1964a), road shorings along the lower West Tamar Road, between Muddy Creek and Rosevears, and the unconventional design of the trans-Tamar Batman Bridge, allowing minimum loading on the potentially more unstable eastern shore.

THE STRUCTURAL AND STRATIGRAPHIC ENVIRONMENT.

The dominant structure is the north-westerly trending Tamar Trough, a probable fault wedge associated with Mesozoic or early Tertiary tensional slip faulting and tilting. Cross-sections of this structure in the upper Tamar area (Longman et.al.,1966) show south-westerly down tilting of the basement rocks, with the Trevallyn Fault marking the axis of the trough and upthrowing the western side. The basement rocks are Permo-Triassic strata, intruded by sheets of Jurassic dolerite, and generally show fault tilts of 5^{o} - 20^{o}. The author's mapping in the northern part of the structure indicates that this fault wedge probably continues beyond the Tamar mouth, but differs in that the western side of the structure is down tilted to the north-east in opposition to the south-westward tilt of the eastern side. North-easterly dips in Permo-Triassic strata are first encountered north of Rosevears and these rocks show a regional dip of about 10^{o} in this direction in the Beaconsfield-West Arm area. This structural change appears to be associated with an apparent side-stepping of the Trevallyn Fault at Rosevears, accompanied by a change in the form of the dolerite intrusion, which to the north forms a long narrow body extending to West Head. This dolerite body is transgressive down to the north-east in the Beaconsfield- West Arm area, and granophyric dolerite near Deviot suggests differentiation in a dyke-like body, as has been demonstrated elsewhere in Tasmania (McDougall in Spry, 1962). There are some suggestions that the Tertiary (?) structure is inherited from the Jurassic structure (Sutherland, 1966), and Palaeozoic-Precambrian features are also probably involved.

Sedimentation in the Tamar Trough was largely non-marine deposition interrupted by periods of erosion and basaltic effusions, and falls into pre-basaltic, inter-basaltic, and post-basaltic phases.

The pre-basaltic sediments consist of clays, sands, gravels, and boulder beds, with lignitic and lateritic horizons, and have a maximum thickness of about 900 feet. They occupy the length of the Tamar Trough, underlying basalt flows and lacking basalt fragments. Their age is Palaeocene-Middle Eocene (Gill and Banks, 1956; Gill, 1962; W.K. Harris,pers. comm.). Minor faulting appears to affect the sediments at Breadalbane, Trevallyn, Strathlyn, Deviot, and Whirlpool Reach, and they have been deeply weathered and dissected since their deposition.

The inter-basaltic sediments consist of similar clays, sands and gravels. Precise datings for these sediments are as yet uncertain, but they probably range from a post-Upper Eocene, Lower Tertiary to a Middle Tertiary age. The sediments include: sands intervening between successive basalt flows as at Bell Bay; sub-basaltic conglomeratic beds containing basalt fragments derived from older flows, as found north-west of Hillwood and in the Rose Rivulet area; and possibly some lateritic soils developed on flows north of Spring Bay and above Strathlyn, which appear to underlie later basalts. Where sediments were deposited upstream from earlier basalt effusions, or at times of minimum erosion, they would lack transported basalt fragments and be difficult to distinguish from the pre-basaltic beds.

The post-basaltic sediments belong to the Upper Cainozoic and include siliceous, doleritic and/or basaltic sands and gravels, in cases not easily distinguished from some of the pre and inter-basaltic deposits. Talus and landslip debris, associated with the present erosive cycle of the Tamar River, extensively cover valley sides. Post-basaltic soils include lateritic and semi-lateritic profiles developed over the basalts, Jurassic dolerites, and Cainozoic sediments. Littoral sands are found around the Tamar mouth and deposits of alluvium and pebble beaches along the river shores.

Volcanism within the Tamar Trough was dominantly effusive consisting of periodic extrusions of basaltic lavas from a number of centres, commencing in the Lower Tertiary and probably continuing into the Upper Tertiary. The eruptive vents for the lavas are not obviously exposed, but a number can be recognised or inferred from criteria such as some of those listed by Burns (1964), from the detailed petrological studies, or from gravity anomalies. The lavas appear to have ascended mainly on fault-lines and the relationships of the probable volcanic centres to the structures of the Tamar Trough are shown in Figure 1. The lavas range from undersaturated alkaline types to saturated tholeiitic types. The distribution of the volcanic rocks is shown in Figure 2. They occur in four main areas: (1) in the lower reaches of the Tamar River, in the Georgetown-Bell Bay area on the east, and the Kelso-Beauty Point area on the west;

(2) in the middle Tamar reaches, from the East Arm-Hillwood area on the east, and the Rowella-Deviot area on the west;

(3) toward the upper Tamar reaches, in the Windermere area on the east, and in the Rosevears-Muddy Creek area on the west;

(4) south of the head of the Tamar, in the Perth-Western Junction-White Hills-St. Leonards area.

Each of these areas will be discussed in detail separately.

LOWER TAMAR AREA (Figures 3 and 4.)

PRE-BASALTIC ROCKS.

Jurassic dolerite bounds both sides of the Tamar in this area. On the west it forms a north-westerly trending transgressive body, dipping to the north-east and intruding Permo-Triassic (?) sandstones and shales with only slight metamorphism along the contact. Dips in these strata exposed in West and Middle Arms indicate regional north-easterly tilting of this western block. On the eastern shore, a dolerite ramp outcrops at Low Head, east of Georgetown, at Bell Bay, and south of Donovans Bay. No intrusive contacts are visible, but the inclinations of joint planes suggest south-westerly tilting. Marked curved and platy jointing occurs in the dolerite at West Arm, Greens Beach, and Low Head, while rocks belonging to the "pegmatitic" zone occur on the southern shore of Bell Bay.

Tertiary sediments, overlying the Jurassic dolerite and underlying basalt flows, are exposed at various points on both the western and eastern shores, up to heights of 150 feet above river level. Launceston Marine Board bores have proved these sediments to depthsof at least 137 feet below Astronomical Low Tide Datum (A.L.T.). Bore sections (Figure 3) show that the sediments are essentially horizontal with regional dips in from the trough margins of less than 3^{o}. The beds consist of light to dark brown, grey and yellow sands, clayey sands, sandy clays, silty clays, and clays, including dense carbonaceous clays. They are generally unconsolidated, and contain pieces of wood, leaf impressions, and ferruginous horizons. The sediments intersected below the basalt at Bell Bay have been dated as probably Eocene (E.D. Gill, pers. comm.).

The basalts overlying these sediments outcrop extensively on both sides of the river up to elevations of 170 feet and fill a valley profile cut in the sediments. Bore logs in the Bell Bay area (McLaren and Taylor, 1961) and the author's petrological studies indicate that at least two flows are present, separated by an interval of erosion and sedimentation.

LOWER OLIVINE-BASALT.

This basalt extends from Donovans Bay through Bell Bay and Middle Island to Beauty Point, and out through Lyetta and Georgetown to the Tamar Heads, thence into Bass Strait. Bore logs and petrological studies suggest a single flow filling a channel following a similar course to that of the present Tamar, (Figures 3 and 4).
At Inspection Head road cut basalt fills a small, steep tributary valley in the Tertiary sediments. Two bores on the foreshore here, (Launceston Marine Board-Inspection

Head Bores 1 and 2, Figure 4), apparently straddled the old valley side; Bore 1 passed through Tertiary sediments to a depth of 70 feet below A.L.T., before being stopped, while Bore 2 intersected continuous basalt to a depth of 59 feet below A.L.T. without passing through it. Similarly, Launceston Marine Board bores at Garden Island and Barrel Rock intersected similar basalt to depths of up to 42 feet below A.L.T. without passing through, but at many points along the Tamar shores the basalt can be observed overlying the sediments above river level. Inland from both shores the base of the basalt rises to elevations of 150 feet (Figure 4) indicating a maximum thickness for the basalt of at least 210 feet, and an average cross-sectional valley slope of 1 in 13 for the pre-basalt Tamar.

The basalt is massive, with strong, irregular to rectangular jointing, and shows cooling columns around Point Effingham, Georgetown, Lyetta, Greens Beach, and Low Head. Some joint planes in bores at Bell Bay show polishing indicating slight movement, and some contain pyrite (McLaren and Taylor, 1961).

In fresh exposures the basalt is a dense, even grained, darkish blue-grey rock, containing sporadic amygdales filled or lined with carbonates, including siderite. The basalt tends to decompose to a soft blue or brown clay on its upper surface, while weathering extends to varying depths and tends to be erratic. At contacts with the underlying sediments, clays are baked and blackish, but the alteration is not intense and rarely extends for more than a few inches, and the basalt tends to become slightly scoriaceous and weathered in a lighter coloured zone up to a few feet in thickness (Plate 1.).

Petrology.

In thin sections (30 slides, Figure 4) the rock is an olivine-basalt consisting of olivine phenocrysts set in a groundmass of feldspar, pyroxene, olivine, iron ore, and interstitial carbonate, chlorite, zeolites, glass, opal and chalcedony (Plate 21).

The olivine ($2V_z$ 88-96°, $\simeq$ Fo 91-76) tends to be glomeroporphyitic and forms 12-17% of the rock as corroded crystals up to 2.5 mm. across, but mostly less than 1 mm.. It is generally partly altered along cracks and margins to limonite, serpentine, or carbonate.

The feldspar forms 38-49% of the rock as laths and allotriomorphic plates showing an undulose extinction. The laths are labradorite (Composition Ab 40-48) ranging up to 1 mm., but mostly less than 0.7 mm. long.

In some sections (257, 267, 319, 341, 365) the laths show a tendency to flow alignment. The pyroxene is almost colourless augite (Z:c 44-46°, 24-27%) forming tiny, intergranular grains, mostly less than 0.2 mm., but up to 1.2 mm. across in rare pyroxene aggregates (368). Iron ore (6-11%) occurs as elongate laths, irregular intersertal masses, and squarish grains, rarely greater than 0.5 mm. in size. Apatite is present as small needles, commonly in the interestal feldspar, while some colourless glass may also be present (343, 365).

The rocks contain variable amounts of late interstitial material forming up to 20% of the section. In cases this material is clearly amygdaloidal in nature, but in others not obviously so and may be deuteric in origin. In some sections (319, 341, 342, 345, 366, 370) this material is predominantly carbonate, including siderite; in others (257, 294, 297, 299, 303, 340, 344, 369) it is predominantly a serpentinitic or chloritic clay; and in some (261, 326) both carbonate and clay are present. In sections (256, 267) from Shear Reef there is interstitial zeolite, with properties resembling chabazite. Brownish green glass or opal is present in a few sections (294, 295, 340, 345, 368) and carbonate, greenish to blackish chalcedony, and green opal fill interstitial amygdales in sections 368 and 367. Sporadic, larger, ovoid amygdales in the rock generally contain a serpentinitic, chloritic or nontronitic clay, or carbonate.

Petrologically the rock is an olivine-basalt resembling the Mersey type of Tasmania (Edwards, 1950; Spry, 1962) but a chemical analysis (Table 1, analysis 1) suggests it is a somewhat basic and alkaline variant of this type. Rare, small xenoliths are present; one noted from Middle Island (368) was 2 x 0.5 mm. across, composed of anhedral quartz and carbonate, and boardered by columnar prisms of colourless augite up to 0.7 mm. long.

Source and Age.

The source of this basalt is problematical. A couple of north-westerly trending, near vertical dykes, a foot or two across, cut the Permian strata on the shore between Boats Crew and Soldiers Point on West Arm. The dykes have silicified and pyritised the host rocks for a few inches out from their contacts, but the original dyke rock is completely decomposed and difficult to identify. Although these dykes may have fed the basalt flow, the lack of any basalt within the immediate vicinity, and the presence of intrusive Jurassic dolerite to the west near Anchor Point, suggests that they are more probably related to the dolerite intrusion. It is possible that the source was not located in the lower Tamar area, either being out in Bass Strait, or upstream in the East Arm area, where pebbles of petrologically similar basalt in sub-basaltic gravels suggest its original extension into this area.

The basalt was erupted following dissection of the underlying Eocene beds. This disconformity probably correlates with the Middle-Upper Eocene disconformity cut in similar non-marine beds in Bass Strait and south-western Victoria (Bock and Glenie, 1965; Esso Exploration Australia Inc.,1966). No soil of any magnitude has developed on the sediments immediately below the basalt (from bore cores - E.D. Gill, pers. comm., and the author's field observations) suggesting that the basalt is not much younger than the sediments and is probably Upper Eocene, or possibly Oligocene in age. A Lower Tertiary age for the lower Tamar flows is also indicated in the middle Tamar area, where, coarse basalt (pre-Lower Pliocene) disconformably overlies a basalt remnant, correlated with the upper flow in the lower Tamar, and gravels containing basalt pebbles apparently derived from the lower flow in question.

INTER-BASALTIC SEDIMENTS.

Several bores in the Bell Bay area revealed a thin inter-basaltic sedimentary horizon, up to about 2 feet thick (McLaren and Taylor, 1961), which separates the upper and lower olivine-basalts. This bed overlies the lower olivine-basalt at an elevation between 80 and 100 feet, and consists of sands, in some cases carrying basalt pebbles.

UPPER OLIVINE-BASALT.

This basalt outcrops less extensively than the lower basalt and is confined to the Bell Bay-Point Effingham area on the east and to the Inspection Head-Beauty Point area on the west. It closely resembles the lower basalt in the field, but shows some petrological differences in thin sections.

In the Bell Bay-Point Effingham area the base of the basalt occurs at elevations between 80-100 feet and is at least 15 feet thick. A steep basalt-sediment contact with some baking is exposed by a land-slide along the cliff, half a mile east of the Comalco wharf, and probably represents an old valley side.

On the west Tamar this basalt outcrops, from above Inspection Head Wharf to Beauty Point Wharf, at elevations of up to 100 feet. It appears to overlie the lower basalt at about an elevation of 50-60 feet on the bank above Inspection Head Wharf, forming a small bench. Similar basalt is found between the two wharves at river level, with no evidence of the lower basalt, but as it occurs within a zone of major land-sliding, large scale downward movements of the basalt may be involved.

Petrology.

In thin sections (15 slides, Figure 4) the upper basalt resembles the lower basalt in its mineralogy and general texture, but differs in that the olivine ($2V_Z$ 88-98°, $\simeq$ Fo91-72) is mostly unaltered and that the rock invariably contains a darkish mesostasis that forms up to 20% of the section (Plate 22). This mesostasis is darkened by minute globules of iron ore, and contains skeletal crystals and acicular sheaves of augite, crystallites of feldspar, and long slender laths of iron ore. The augite in the rock tends to have a faintly pleochroic purplish tint, particularly within the mesostasis, and is probably slightly titaniferous. Most sections show some interstitial or amygdaloidal brownish green opal and chalcedony, with carbonates in some sections.

Petrologically the rock approaches a near-saturated alkali-olivine-basalt, (analysis 2, Table 1) resembling a slightly basic variant of the Mersey Type (Edwards, 1950; Spry, 1962). However the rock shows a higher iron content than previously found in such basalts in Tasmania (analyses 94-107; Spry, 1962), and the excess iron presumably darkens the mesostasis.

Minerals lining amygdales and veinlets in the basalt were collected from the excavation at the 50-60 feet level above the Inspection Head shore. Minerals identified by X-ray powder patterns and other means included chabazite, apophyllite, phillipsite, calcite, siderite, gonnardite(?) and rare natrolite.

A number of loose blocks of highly scoriaceous and amygdaloidal basalt were found on the shore south of Beauty Point (grid 7550E-2968N). In a thin section (240) the rock is an olivine-basalt, differing from the other basalts in the area in containing an abundant black glass. This basalt is probably exotic, as it is found near an old tramway and loading wharf area originally operated by the Tasmanian Mine from Beaconsfield; ~~suggesting~~ it may have been brought in as ballast, possibly from Victoria.

POST-BASALTIC SEDIMENTS.

A possible consequence of the eruption of the lavas in the lower Tamar area may have been diversion of the Tamar out of its valley just north of Beaconsfield, through West Arm and the wide valley between West and Badger Heads. Gaps in bedrock outcrops associated with sand and gravel deposits of probable Tertiary age (dipping at over 30^o north-easterly, 2 miles S.W. of Beaconsfield; Green, 1959) occur along this general line and may represent the course of an old channel. However, detailed stratigraphical and geomorphological work would be required to prove this. The pronounced westward swing of the old Tamar course preserved by the younger basalt at the north end of Long Reach in the Middle Tamar (Figure 6) is also of interest in respect to such a diversion, and re-diversion of the Tamar to its present course would presumably have resulted from the outpouring of this later lava.

Widespread clay, sand, and gravel beds disconformably overlie the basalts in the lower Tamar, and include siliceous sands and gravels described by Kershaw (1955, 1958), Green (1959), McLaren and Taylor (1961) and Matthews (1966). The sediments are generally unconsolidated, but in Kelso Bay (grid 7350E-3600N) strongly silicified quartz conglomerate outcrops at river level. Well developed benches are associated with these sediments, and may relate to old sea-level stands. Benches are found at about the 250 and 200 feet levels east of Beauty Point, and a prominent and widespread terrace stands at between 100 and 150 feet in elevation in the Bell Bay, Georgetown, and Lyetta areas, and near the southern end of West Arm. A possible old shore line or storm beach deposit at a comparable elevation occurs just north-west of Beaconsfield (Green, 1959), while there is evidence of a former shore line cut at about 110 feet above MLWS south of Greens Beach (Kershaw, 1958). Other benches attributed to marine levels have been recorded on the West Tamar at 70-80, 40-50, 25-30, and 10-15 feet above sea level (Green 1959; G.M. Dimmock, K.D. Nicholls, and R.C. Kershaw, pers. comm.). Similar levels on King and Flinders Islands (Jennings, 1959b; Kershaw and Sutherland, unpublished manuscript) are probably related to marine levels in the last Interglacial and Post-Glacial periods, while the higher levels are probably older than the last Interglacial.

In a number of places nodular ironstone "oertstein" has developed on the Upper Cainozoic sediments and older rocks, and is particularly extensive east of Bell Bay. Similar developments on the Western Plains of Victoria are considered to have formed under Pleistocene climatic conditions (Gibbons and Gill, 1966). A few of the ironstone occurrences, such as is developed on Lower Tertiary sediments to the east of Georgetown, may represent remnants of older lateritic surfaces.

Pleistocene windblown littoral sands in the Tamar Heads region have extended inland over the older post-basaltic deposits as far south as Bell B ay. Other superficial deposits include the extensive landslip and talus debris associated with the present erosive cycle of the Tamar River. Many of the slides, presumably, were initiated by active channel cutting of the Tamar with sea-level fall in the last Glacial period. Recent deposits in the area include the coastal calcareous sands forming stabilised dunes and beach ridges in the Greens Beach-Kelso and Low Head-Georgetown area.

MIDDLE TAMAR AREA (Figures 5 and 6).

PRE-BASALTIC ROCKS.

Jurassic dolerite outcrops on both sides of the valley in this area, continuous with, and showing a similar structure to, the outcrops in the lower Tamar area. At Hillwood, however, further outcrops appear, suggesting some cross faulting (Figure 1). The dolerite of the eastern shore resembles that of the upper differentiation zones (McDougall in Spry, 1962) and thin sections (397, 61-32: Tas. Dept. Mines) of samples from Egg Island and Long Reach show a fairly abundant mesostasis typical of such zones. A dolerite from the western shore at Deviot (grid 8566E-2067N) shows about 60% mesostasis and approaches a granophyre in composition. The dolerite along the shore south of Deviot is extensively decomposed and this may indicate a fault zone, or a mesostasis-rich differentiate more susceptible to weathering, or both.

Sands and clays, similar to the sub-basaltic beds in the lower Tamar, occupy the central part of the valley. These sediments reach elevations of over 400 feet and extend to at least 308 feet and 120 feet below mean river level at Long Reach and Whirlpool Reach respectively (Maunsell and partners, 1962; Hughes, 1959). The beds show a regional, depositional(?) south-westerly dip of a few degrees at Long Reach and East Arm, and south of

Deviot where they directly overlie the dolerite the dips are north-easterly at between 5-10°. Locally, as a result of later faulting, landslipping, and lava flow, the sediments show considerable variation in attitude, ranging from gentle warps forming small dome and basin structures to steep, near vertical tilts. Well developed steep jointing occurs, and along the Deviot and Redwood Bay foreshores a prominent north-easterly trending joint set is associated with a number of more irregular sets. Small faults cut the sediments, trending north-westerly and westerly at Whirlpool Reach (Figure 7) and north-easterly at Deviot (grid 8567E-2063N).

Bore logs in the lower part of the sedimentary sequence (Maunsell and Partners, 1962; Hughes,1959) record clays as the dominant lithology, but some of these may represent altered feldspathic sandstones, with the original structure being destroyed on compression (see Longman, 1966 p.20). In some of the Long Reach bores (nos 5,6,7 and 8) the logs show interbedded bands of "basalt", up to 3 feet thick and down to depths of 250 feet below mean river-level. This seems to suggest eruption of minor flows during the sedimentation. However, these "basalt" bands may represent the passage of the drill through boulders or boulder beds containing fragments of rock derived from the finer grained top zone of the

Jurassic dolerite intrusion. This cannot be resolved at present, as the drill cores in question could not be located. Hughes (1959) records narrow beds of volcanic ash mixed with Tertiary clays on the east shore of Whirlpool Reach, but the present author has been unable to verify these.

Outcrops of these sediments are poor and mainly restricted to the Tamar foreshore, where exposures consist of clays and interbedded sands, with some hard siliceous horizons as at Deviot (grid 8522E-2168N) and Long Reach (grid 8403E-2927N). Ferruginous horizons with limonitic concretions are common and large entrail-like concretions up to over 10 feet across occur at Ruffins Bay, (Plate 2), near Rocky Point and at the west end of Spring Bay. Ramifying, limonitic, tube-like structures, suggestive of infilled worm burrows, and pieces of limonitised wood occur at Ruffins Bay and the west end of East Arm and Spring Bay. Disorientated, limonitised fossil shells of the freshwater mussels <u>Prophyria johnstoni</u> and <u>Alathyria tamarensis</u> (McMichael, 1957) are commonly present, particularly around Spring Bay. Thin clay pellet horizons were observed in sandstone at Deviot (grid 8567E-2063N) and East Arm and a horizon of carbonaceous clay noted at Spring Bay (grid 8503E-2043N). Palynological dating of the carbonaceous clay indicated a Middle-Upper Eocene age (W.K. Harris, pers. comm.).

Mottled friable grit and sand beds up to four feet thick are exposed at Newmans Bay (grid 8534E-2342N), dipping north-easterly at 15-20° and disconformably overlying clays, and similar grits occur at Whirlpool Reach (grid 8419E-2327N). These grits contain angular to rounded quartz grains in an abundant, patchy, argillaceous matrix with pellets of dark claystone and nodules of pink and white clay.

Dolerite conglomerates, up to at least 50 feet in thickness, underlie the flow of coarse basalt north of Hillwood and south of East Arm, and are well exposed in the road cuts at the East Tamar Highway-Batman Bridge Road junction (Plate 3). They consist mostly of rounded fragments of Jurassic dolerite, commonly a few inches across, but include boulders up to several feet across, in a clayey matrix. One pebble collected from the conglomerate north of Hillwood (grid 8945E-2312N) in thin section (189) proved to be an olivine-basalt petrologically identical to the lower olivine-basalt in the lower Tamar area. This indicates that the conglomerates are younger than, and probably disconformably overlie, the Palaeocene-Middle Eocene beds, and they are tentatively correlated with the interbasaltic sediments between the lower and upper flows in the lower Tamar

Large boulders and blocks of Jurassic dolerite occur on the east bank of Whirlpool Reach in the vicinity of the Batman Bridge. These range to over 12 feet across, and some are partly bauxitised, suggesting a bed-rock outcrop. Bores put down within this area, however, passed through into underlying Tertiary clays at depths between 5-17 feet, (Tasmanian Dept. Public Works, 1957; Hughes, 1959). Thus, some or all of the dolerite here represents an old talus deposit, either mantling a narrow underlying dolerite ridge protruding up into the Tertiary beds, or derived from the dolerite outcrop on the western bank of Whirlpool Reach. The deposit appears to mark a constriction in the pre-basaltic channel of the Tamar through Whirlpool Reach (Figure 6) suggesting it may pre-date the coarse basalt, and be comparable in age to the dolerite conglomerates in the Hillwood-East Arm area.

Basaltic lavas outcrop extensively in the middle Tamar area, disconformally overlying the Lower Tertiary sediments. Four distinctive petrologies have been recognised and are dealt with separately.

PORPHYRITIC OLIVINE-BASALT.

This rock is restricted to a single small out-crop below the H.E.C. pylon on the west bank of East Arm (grid 8700E-2700N) at an elevation of about 250 feet. The basalt appears to dip to the north and cooling columns in the basalt dip south at about 45°. It appears to underlie the flow of coarse basalt capping the hill above and either represents a remnant of an old valley fill or part of a neck.

Petrology.

In thin sections (5 slides, Figure 6) the basalt is strongly glomeroporphyritic, containing phenocrysts and micro-phenocrysts of olivine, feldspar, and pyroxene set in a groundmass of feldspar, pyroxene, olivine and iron ore, interspersed with a darkish mesostasis (Plate 3). The olivine ($2V_z$88-101,$\simeq$ Fo90-64) forms 6-13% of the rock as fresh, corroded phenocrysts and grains ranging up to 4 mm. across. The feldspar phenocrysts (29-38%) are up to 2.5 mm. long and are composed of zoned labradorite ranging in composition from about Ab40 to Ab52. The pyroxene (26-31%) occurs generally as micro-phenocrystic grains mostly between 0.1-0.5 mm., but rarely reaching 1.5 mm. across. It is pale brown augite ($2V_z 58^\circ$, Z:c 45-46°) and forms separate aggregates, or clusters around the olivine and feldspar phenocrysts, ~~and~~ tending to intergrow with the latter. The iron ore forms numerous small inclusions in the phenocrysts, and thin laths and irregular grains rarely larger than 0.5 mm. In polished thin section (413) it is largely altered to leucoxene. The mesostasis forms up to 21% of the rock and closely resembles that described for the upper olivine-basalt in the lower Tamar area. No well developed vesicles or amygdales are present, but some of the mesostasis contains a zeolitic core. In most slides the phenocrysts tend to grade into the groundmass, but in section 325, from a specimen near the basalt contact, the groundmass is much finer grained and distinct from the phenocrysts. No mesostasis occurs in the specimen and iron ore is dispersed in numerous small squarish grains that also form prominent borders around the olivine phenocrysts.

The basalt is a near-saturated type (analysis 3, Table 1), mineralogically resembling the upper olivine-basalt from the lower Tamar area, but with higher alumina, lime, and soda, and lower iron ~~ore~~ and magnesia. This presumably reflects the preponderance of phenocrystic feldspar in the rock, and texturally the basalt resembles the Waratah Type of Edwards (1950). The basalt is tentatively correlated with the upper olivine-basalt in the lower Tamar, and the porphyritic texture is considered to represent relatively slower cooling near or within the vent that fed the downstream flow.

OLIVINE-NEPHELINITE.

This rock forms a small flow north-east of Spring Bay between 100 to 200 feet above river-level. It has a maximum thickness of about 50 feet and appears to occupy a small southerly trending valley cut in the Lower Tertiary sediments. The rock is dense, contains small peridotite nodules, and is strongly weathered to reddish lateritic kraznosem soils.

Petrology.

In thin sections (11 slides; Figure 6) the rock contains peridotite nodules, phenocrysts of olivine, and grains of pyroxene, iron ore and apatite, set in a feldspathoidal mesostasis (Plate 24).

The peridotite nodules form up to 5% of the rock, ranging to over a centimetre across, and consist mostly of olivine ($2V_z$ 86-96°, $\simeq$ Fo 94-76), a little clino-pyroxene ($2V_z$ 67°, Z: c 50°), resorbed ortho-pyroxene with exsolved clinopyroxene, and some spinel. The olivine is allotriomorphic, mostly between 2-3 mm. across, and shows strain polarisation and translation (extinction) lamellae.

The phenocrystic olivine (12-21%) includes many crystals with strain polarisation and translation lamallae which probably represent xenocrysts derived from the peridotite nodules. Truly phenocrystic olivines ($2V_z$ 92-98°, $\simeq$ Fo 84-72) with euhedral outlines are mostly less than 1 mm. across. Rare pyroxene xenocrysts are mantled with zoned overgrowths of titan-augite (228). Rare accidental xenocrysts of zoned feldspar occur (272) and accidental xenoliths of feldspathic material, probably pieces of fused Tertiary sediment, are partially or completely replaced with small, inwardly projecting, columnar and acicular augite (271, 272, 282, 286, 315).

The pyroxene (29-41%) forms small prismatic grains and rosettes, rarely exceeding 0.5 mm. across, and is a pale purplish, pleochroic, zoned titan-augite (Z: c 45-58°). Iron ore (6-9%) occurs as squarish or irregular grains, granules, and granular aggregates, up to 0.6 mm., but mostly less than 0.2 mm. across. Apatite (2-5%) is present as coarse to slender prisms up to 1.5 mm. long. The feldspathoidal mesostasis tends to be hyalopilitic, and consists of a colourless to cloudy glass, containing greater or lesser amounts of nepheline, acicular crystallites, and in some cases indeterminate chloritic(?) material (271). In some sections (272, 286, 315) the groundmass is extremely fine grained and dustings of iron ore give the rock an uneven cloudy appearance. In other sections (228, 271, 273) the rock is more coarsely crystalline and the mesostasis forms large poikilitic areas, with nepheline crystals reaching 2.5 mm. across. Minor amounts of interstitial zeolites (including stilbite and phillipsite (?)) and alkali feldspar may be present. In section 228 there are oval amygdales, 1 mm. across, filled with analcite (?) and clay. A "pegmatitic" vein, 2 mm. wide, with diffuse margins, cuts section 277. The vein contains numerous randomly orientated flakes of biotite, up to 0.5 mm. long, some prismatic and strongly pleochroic titan-augite, and acicular apatite, in fine grained nepheline-glass mesostasis.

A coarse pegmatitic variety of the rock (sections 248, 411) occurs at grid 8609E-2550N. It lacks olivine and contains a complex intergrowth of pyroxene and nepheline with an abundant mesostasis (Plate 25). The pyroxene is zoned sodian? titan-augite, deeply coloured and strongly pleochroic with X pale fawn, Y violet and Z purple-violet. Optically the crystals show a range in $2V_z$ of 41° (core) to 70° (rim) and Z:c $38-48^\circ$ (core) to $48-56^\circ$ (rim), with some pale coloured crystals showing a decrease in Z:c from 52° (core) to 46° (rim). The crystals are either prismatic, or form graphic to arborescent intergrowths with the nepheline and reach over 6 mm. across. Some grade or alter marginally to greenish aegirine-augite (Z:a 46° (core) - 18° (rim)) or show some corrosion and resorption, being bordered and replaced by iron ore. The nepheline crystals also reach several mm. in length, and show some zoning and alteration to analcime. Iron ore is present as squarish, skeletal and lath-like crystals of titano-magnetite or ilmenite, up to 1.2 mm. long and largely altered to leucoxene. The mesostasis consists of numerous crystallites and radiating sheaves of skeletal and zoned laths of alkali feldspar up to 4 mm. long, some acicular aegirine-augite and apatite, and indeterminate chloritic material and interstitial zeolites.

Amygdales, up to 2 mm. across, are lined with analcime and a radiating fibrous zeolite with straight extinction, negative elongation and very low birefringence (possibly gonnardite), and are filled with stilbite and phillipsite (?).

A chemical analysis of the olivine-nephelinite (analysis 16, Table 1) resembles that of an olivine-nephelinite from Derby, N.E. Tasmania (analysis 110; Spry, 1962), but is slightly higher in alumina and lower in magnesia. The pegmatitic phase, with the alkali feldspar mesostasis and no olivine, presumably would show a relative increase in silica, soda and potash, and a decrease in magnesia.

Source and Age.

Pegmatitic phases, such as that just described, are found in probable volcanic necks in the Shannon Tier and Scottsdale districts in Tasmania (Edwards, 1950; Marshall et. al., 1965), and this may mark the approximate position of the vent for the Spring Bay olivine-nephelinite.

The flow post-dates erosion of the underlying Lower Tertiary sediments. Its lateritised surface appears to extend below the base of the adjacent flow of coarse basalt (pre-Lower Pliocene), suggesting that it represents an older, more weathered residual of Oligocene-Miocene age.

NEPHELINE-BASANITE.

This rock is confined to the fore-shore at Deviot below the road junction south of the Post Office, where it overlies the Lower Tertiary sediments. It is at least 10 feet thick, massive, with a fine grained margin passing up into coarser grained rock, and contains rare peridotite nodules.

Petrology.

In thin sections (392, 583, 584, 586) the fine grained rock is porphyritic with olivine phenocrysts set in a groundmass of feldspar, pyroxene, a little olivine, iron ore and apatite, associated with a feldspathoidal and zeolitic mesostasis (Plate 26).

The olivine ($2V_z$ 87-102°, $\simeq$ Fo 92-62) forms 18-20% of the rock and is only slightly altered to serpentine. The phenocrysts are corroded, range up to 2.2 mm. across, but are mostly less than 0.5 mm. across, and grade down into groundmass grains. The larger phenocrysts consist of interlocking grains and show translation lamellae. Rare augite phenocrysts, up to 2 mm. across, contain colourless cores ($2V_z$ 55-65° centre to 49-52° edge; Z:c 37° centre to 44° edge) riddled by corrosion and small inclusions of olivine. These are outgrown with purplish titan-augite, sub-ophitically intergrown with the groundmass feldspar. Similar titan-augite (27-30%) occurs as intergranular grains up to 0.6 mm., but mostly less than 0.2 mm. across. The feldspar (22-29%) forms laths and zoned anhedral plates of labradorite, up to 1 mm., but averaging about 0.6 mm. long. Iron ore (7%) forms idiomorphic and skeletal crystals up to 0.8 mm. long, moulding and enclosing the groundmass grains. Apatite (3%) is prominent as coarse prisms up to 0.8 mm. long, and as small needles in the mesostasis, which is a clear glass containing euhedral to subhedral nepheline (up to 8%), accompanied by analcime and other zeolites, and small flakes of biotite. Numerous round amygdales, 0.2 to 2 mm. across, are scattered through the rock and are filled with stilbite and other zeolites.

The coarse phase of the rock (390,393, 585) ~~Plate 27)~~ is olivine-basalt containing about 25% olivine ($2V_z$ 92-102°, $\simeq$ Fo 84-62). The pyroxene forms large plates up to 2.5 mm. across in a sub-ophitic to ophitic intergrowth with the olivine, feldspar and iron ore. It is strongly zoned, deeply coloured sodian ? titan-augite ($2V_z$ 71°_{core} to 77°_{rim}, Z:c 48-54$^\circ_{core}$ to 48-65$^\circ_{rim}$), pleochroic from deep violet to brownish yellow. Some crystals show deeper coloured cores, others deeper coloured borders. The feldspar forms laths and anhedral plates of labradorite, up to 1.8 mm. long, zoned from about Ab35 to more sodic compositions, and mantled with alkali-feldspar. The mesostasis consists of numerous small laths and microlites of alkali-feldspar (commonly curved and spherulitic), prismatic apatite, small grains and crystallites of iron ore, small biotite flakes, and an analcime-rich zeolitic base with only minor amounts of nepheline apparent. Spherules of radiating zeolite with straight extinction and negative elongation are present and may represent gonnardite.

Analyses of the fine and coarse grained phases of the rock (analyses 14 and 15, Table 1) are similar, but the coarse phase is slightly richer in silica and poorer in soda, which probably accounts for the disappearance of modal nepheline in this phase.

Source and Age.

The localised outcrop of this rock suggests it was extruded as a small flow from a nearby source, and the eruptive point may be marked by the small outcrop of coarser phase rock exposed at low tide-level. There are some indications of cross-faulting in this vicinity, and this point lies near the apparent intersection of these faults.

The flow overlies and post-dates the Lower Tertiary sediments in the area, but its precise age is uncertain, although its general relationship to the nearby outcrops of coarse basalt suggest it may be the older eruption.

COARSE OLIVINE-BASALT.

This rock occurs very extensively, and

occupies a valley profile cut in the Tertiary sediments. It outcrops up to elevations of about 600 feet, and drilling has proved it to at least 100 feet below the river level (Maunsell and Partners, 1962). The pre-basalt valley sides slope from about 1 in 10, to about 1 in 2 along the central channel. A thick flow caps the country between Hillwood and East Arm, forming cliffs a hundred feet high north of Craigburn, (Plate 5.) Contours drawn on the base of the outcrops (Figure 6) suggest the possibility that they may all represent remnants of a single extrusion, filling the old valley of the Tamar to a maximum thickness of the order of 400 feet. Alternatively, more than one flow may be represented, with some or all of the outcrop at lower levels representing a flow, or a series of flows, that filled the old valley up to elevations of about 150 feet, prior to eruption of an upper flow. No positive evidence for multiple flows or of any significant faulting of the coarse basalt was observed in the field, but poor exposures and extensive blanketing of hillslopes with landslip and talus debris obscure the detailed relationships between outcrops. Sedimentary horizons within these rocks in the bores at Long Reach and Whirlpool Reach (Maunsell and Partners, 1962; Tasmanian Department of Public Works, 1957) are possibly accounted for by landslip movements, clastic dykes, and intricate, partly intrusive contacts, as described in detail later. Thin section examination of samples from numerous localities and different levels revealed several petrological variations, but all are reconcilable with possible natural variation, including differentiation, within a single thick flow.

The rocks are bluish grey when fresh, generally massive and medium grained. Some exposures and contact zones are strongly weathered and decomposed, and in places simulate conglomerates, as at grid 8459E-2304N and grid 8705E-2120N. Chilled contact zones are generally absent and a relatively large grain size is commonly maintained right up to the contact. Irregular patches and veins of more coarsely grained pegmatites cut the rocks (Plate 6) at Long Reach, Rowella, East Arm, and on the plateau above Craigburn (Figure 6). Peridotite nodules up to a few cms. across occur in the rocks along the western foreshore of East Arm and leave cavities on weathered surfaces.

The rocks are well jointed. Close, platy jointing is developed near contacts, as at East Arm (grid 8422E-2756N), Moriarty Reach (grid 8467E-2631N) Long Reach (grid 8330E-3011N) and Whirlpool Reach (grid 8441E-2303N), and passes up into blocky, rectangular, and irregular jointing. The blocky jointing is commonly developed both normal and parallel to the basal contacts, and becomes ~~may be~~ inclined at dipping contacts, as on the Batman Bridge Road (grid 8663E-2660N), on Redwood and Drumstock Islands, and along the Rowella shore. A zone of close vertical jointing on top of the flow capping north of Hillwood (Figure 6) is interpreted as a remnant of the uppermost zone of the flow. Polygonal cooling columns develop in a number of places, and north of Craigburn (grid 8700E-2325N) they form inverted fan structures (Plate 7). Small north-westerly and westerly trending dislocations, including reverse movements, cut the rocks on the foreshore south of the Batman Bridge, with throws of up to about a foot (Figure 7; Plate 8).

Baking along sediment-basalt contacts is most marked along the sides of the central lava channel, where clays are baked and blackish in colour over a few inches to a couple of feet away from the contact. Small prismatic cooling columns up to six inches long occur in baked clay at Long Reach (grid 8345E-2980 E), and hard chert hornfels were found at East Arm (grid 8800E-2624N), and Moriarty Reach (grid 8395E-2744N). In several places along steep contacts exposed on the Tamar shores, the contacts are extremely irregular. Dykes and pillow-like lobes of basalt occur on the foreshore at Davis Cove (Figure 8), and a thin sill, 9 inches to 2½ feet thick (Plate 9), shows irregular flame-like structures along the contacts. The rock in these bodies is badly decomposed and strongly scoriaceous, with a more coarsely scoriaceous interior zone ranging up to about a foot across. The enclosing sediments show steep dips and although these may be due in part to rotational slipping associated with the present erosive cycle, the evidence tends to suggest tilting or slumping concomitant with the intrusions. These intrusive bodies do not necessarily represent feeders, but may be merely localised intrusion from the passage of lava over unconsolidated and water saturated sediments. Similar irregular contacts occur on the Long Reach foreshore at grids 8425E-2923N, 8299E-3045N, and at Spring Bay (grid 8545E-2342N). Numerous pillow-like structures occur at the contacts exposed on the eastern foreshore south of the Batman Bridge (Figure 7) with contorted and near-vertical sediments (Plates 10 and 11). These include near-isolated "pillows" showing necking (Plate 12) and in some cases small secondary lobes (Plate 13). Thin, clastic veins of friable sandstone, up to six inches wide, cut the volcanic rocks in places (Plate 14), and some of the "pillow" bodies show cores infilled with sediment. Whether the sediment was derived from the under-lying sediments on contact with the lava, or whether it is post-volcanic infilling, is not clear from these exposures. At Spring Bay (grid 8545E-2342N), however, where further clastic veins are associated with a part-intrusive basalt contact, the sediment appears to have intruded up into the lava from the underlying sediment. It is perhaps significant that where the bores at Long Reach (Maunsell and Partners, 1962) and Whirlpool Reach (Tasmanian Department of Public Works, 1957) intersected sediments interbedded in the coarse basalt these were located near the steep margins and were lacking within the deeper parts of the basalt column. Thus, the logged sediment-volcanic rock interlaying may represent a single complex and part-intrusive contact, as observed in exposures elsewhere, rather than a series of flows with intervening sedimentation.

The coarse basalt carries sporadic veins, patches and amygdales infilled with deuteric and/or secondary minerals, but noticeably vesicular rock is confined to the minor intrusions along some of the contacts. Amygdales in the quarry half a mile north of Craigburn release fluid when broken open, and minerals collected from this site, and from amygdales elsewhere in the coarse basalt, are described under petrology.

<u>Petrology.</u>

In thin sections (63 slides; Figure 6) the rocks are medium grained and contain olivine, plagioclase, pyroxene, iron ore and apatite, accompanied by an interstitial zeolitic and feldspathic mesostasis.

Textures range from porphyritic and intergranular, to sub-ophitic or ophitic and intersertal. In a few sections from samples near contacts the rocks grade into fine grained basalts.

Olivine ($2V_z$ 86-102°, ≃ Fo 94-62) forms 9-35% of the rock, with the olivine-rich varieties grading into picrites (Plate 29), but the majority of the slides carry 15-25% olivine. Crystals are generally corroded, and range from small groundmass grains to phenocrysts over 4 mm. across. The olivine is strongly glomeroporphyritic in sections with an intergranular groundmass, but this becomes masked in sections with coarser sub-ophitic to ophitic fabrics. It generally shows some alteration to serpentine or "bowlingite" and may contain small inclusions of iron ore.

The peridotite nodules in the rock from East Arm foreshore consist of interlocking olivine ($2V_z$ 86-102°, ≃ Fo 94-62), up to several mm. across, with strain polarisation and translation lamellae, and a little partly resorbed clino-pyroxene ($2V_z$ 53°, Z:c 46°), (199). Some of the larger olivine crystals in many of the sections show translation lamellae and appear to be derived from disaggregation of such nodules.

Feldspar (20-48%) forms laths and subhedral to anhedral plates of zoned labradorite (composition from

Ab36 to Ab48), ranging up to about 4 mm. long and twinned on the Albite, Carlsbad and Pericline laws. The pyroxene (24-38%) forms prismatic intergranular grains, up to about 0.5 mm. across, or large plates, up to about 3 mm. across, sub-ophitically to ophitically intergrown with olivine, feldspar and iron ore. It is a purplish brown titan-augite, with weak colour and pleochroism in some slides, but with marked colour zoning and pleochroism in other slides. The outer zones of the crystals are usually the deeper coloured with Z purple or violet, Y violet, and X brownish yellow. Optically, the titan-augite shows considerable variation in the optic axial ~~angle~~ and longitudinal extinction angles. Numerous measurements provided the following values, and showed that there is generally an overall increase in both $2V_z$ and Z:c values from the crystal core to its rim; small, pale coloured, intergranular grains gave $2V_z$ $73-78^{\circ}$ and Z:c $42-52^{\circ}$ (core) to $48-55^{\circ}$ (rim); small to medium sized grains with moderate to deep colour gave $2V_z$ $50-57^{\circ}$ (core) to $58-71^{\circ}$ (rim) and Z:c $39-47^{\circ}$ (core) to $45-61^{\circ}$ (rim); and large plates with moderate to deep colour gave $2V_z$ $54-67^{\circ}$ (core) ~~and~~ to $62-71^{\circ}$ (rim) and Z:c $42-55^{\circ}$ (core) to $46-60^{\circ}$ (rim). These values suggest that some of the titan-augites grade into sodian varieties in which the violet-brown titanium colours largely mask the greenish tinges typical of sodian pyroxenes. Some sections (168, 169, 192, 193, 223, 224, 230, 330, 61-31:Tas. Dept. Mines) include glomeroporphyritic colourless augite ($2V_z$ 53°, Z:c 48°), generally with corrosion riddled interiors, but the bulk of the pyroxene in these sections is intergranular. The more deeply coloured and pleochroic titan-augite generally occurs in sections with the coarse sub-ophitic textures, or, if intergranular, in association with an abundant chloritic, feldspatho-zeolitic mesostasis. This titan-augite is commonly altered on its margins to aegirine-augite where it is in contact with the mesostasis. Iron ore (6-11%) forms skeletal crystals, irregular masses and laths, generally less than 1 mm. in legth, and small grains and crystallites within the mesostasis. It is a titano-magnetite or ilmenite largely altered to leucoxene. Apatite (2-4%) is present as small needles and prominent coarse prisms up to 0.7 mm. long.

The rocks show considerable variations in the proportions and nature of the mesostasis, which may form up to 32% of the rock. Four main types can be distinguished, but these tend to be gradational, and some of the rocks show two or more of the types in the one slide.

In many of the sections the mesostasis consists of intersertal feldspar and zeolite. Mesostasis type 1 (13 slides) consists of an intersertal, alkaline plagioclase or alkali feldspar, associated with small prisms and crystallites of pyroxene, commonly altered to a greenish soda-pyroxene, flakes of biotite, needles of apatite, grains and globules of iron ore, some interstitial zeolite and some clear glass. Mesostasis type 2 (24 slides) is similar, but interstitial zeolite predominates and becomes particularly abundant in some sections (168, 169, 223, 232, 330, 396; 61-29, 61-31, Tas. Dept. Mines). The interstitial zeolites include potash-rich analcite and a radiating, length fast mineral, with straight extinction and low birefringence, possibly gonnardite. In sections with mesostasis type 2 the iron ore tends to be idiomorphic and separated from the mesostasis, and if the titan-augite present is intergranular it generally only shows faint body colour and pleochroism. Mesostasis type 3 (17 slides) consists of numerous small laths and curved to spherulitic microlites of alkali feldspar, associated with prisms of apatite, small grains and crystallites of iron ore, and flakes of biotite, in a zeolitic-analcite rich base with indeterminate chloritic material. It is abundant in some sections (170, 184, 220, 237, 250, 252, 289, 292, 413) where it contains skeletal titan-augite crystals and prominent, thin laths of iron ore. Mesostasis type 4 (3 slides) resembles type 3, but lacks chloritic material, and grades into type 2. Mesostasis types 3 and 4 are invariably associated with deeply coloured titan-augite, and are usually developed in the coarser "pegmatitic" phases of the basalt. The distribution of the predominant mesostasis type found in collected samples, in association with the texture of the pyroxene, is plotted in figure 6. No consistent pattern appears to be developed, although mesostasis type 3 tends to be most common in the lower profiles, within the old buried channel of the Tamar. The rocks resemble the Branxholm (intergranular pyroxene) and Deloraine (sub-ophitic to ophitic pyroxene), Types of Edwards (1950); see plates 27, 28 and 29. Chemical analyses (analyses 4-6, Table 1) show that the coarse basalts range from undersaturated to near-saturated compositions and are alkaline-rich rocks approaching basanites in composition. The picritic phase (analysis 5) is much richer in magnesia and poorer in silica and alumina compared with the more feldspathic and mesostasis-rich phases (analyses 4 and 6).

Porphyritic olivine-basalt: A rock from Spring Bay (grid 8544E-2341N) in thin section 171 shows phenocrysts of olivine and plagioclase grading into a fine grained groundmass of feldspar, pale coloured augite, iron ore and apatite, with patches of zeolites. The plagioclase phenocrysts are zoned from labradorite to andesine, reach 2 mm. in length, and are sub-ophitically intergrown with, and poekilitically enclose, small grains of groundmass minerals. Small inclusions of sediment (?), up to 0.3 mm. across, are scattered through the rock, almost completely replaced with very fine grained pyroxene, and show apparent corona structure. The rock texture suggests a rapid chilling of the rock as normal crystallisation was proceeding. The specimen was collected adjacent to a contact where the coarse basalt partly intruded the underlying sediments, and another specimen taken only a few feet away in the same outcrop showed texture more typical of the coarse basalt (431). This suggests quick chilling where a tongue of lava intruded into the underlying, and probably wet, sediments.

Pegmatitic Veins: Thin sections (197, 198) of a "pegmatitic" vein in picritic coarse basalt from the East Arm foreshore, show irregular margins up to 7 mm. wide bordering the interior of the vein. These margins are composed of stout, zoned crystals of labradorite-andesine containing numerous small inclusions of apatite, and ophitically intergrown with sodian? titan-augite and large, partly skeletal, crystals of iron ore. The titan-augite is strongly zoned with deep coloured and strongly pleochroic outer margins ($2V_z$ $67-74^{\circ}{}_{core}$ to $74-84^{\circ}{}_{rim}$, $Z:c$ $35-51^{\circ}{}_{core}$ to $43-66^{\circ}{}_{rim}$). Olivine is very sparse in comparison with the host rock and is strongly corroded and more fayalitic in composition ($2V_z$ 100-105°, ≃ Fo65-55); it tends to be altered to "bowlingite" and to be replaced by iron ore on the outer margins. Small amounts of mesostasis related to type 2 are present. The minerals ~~zones~~ reach up to 2.5 mm. across in size and show a slight tendency to alignment normal to the borders of the vein. The interior of the vein is up to 12 mm. wide and is largely mesostasis types 3 and 4, containing sporadic and relatively smaller crystals of the minerals composing the marginal zones. Titan-augite crystals within the inner zone tend to be paler coloured on the outer edges.

Pegmatites: Pegmatitic phases up to several feet across occur in the coarse basalts, and thin sections (191, 409, 658) of samples from the plateau above Craigburn (grid 8767E-2435N) and on Long Reach foreshore show a coarse intergrowth of olivine, feldspar, pyroxene, and iron ore, associated with an analcime rich mesostasis (Plate 31.)

The olivine ($2V_z$ 100-105°, ≃ Fo 65-55) forms 10% of the rock as deeply corroded crystals up to 7 mm. in length. Some of the olivine is rimmed by iron ore and in some cases crystals are ophitically or dendritically intergrown with the feldspar and pyroxene. The feldspar forms laths and plates of labradorite (36%) up to 9 mm. long. It is zoned from about Ab36 to more sodic compositions, and is commonly mantled with overgrowths of alkali feldspar (16%). These overgrowths are rarely greater than 0.5 mm. in width and are riddled with numerous inclusions and intergrowths of pyroxene, iron ore and apatite, commonly in a graphic texture. Pyroxene (21%) occurs in large ~~ophitic~~ plates of sodian ? titan-augite ophitically intergrown with the feldspar, with strong colour zoning and pleochroism, and the outer zones are mostly deeper coloured, although some are paler coloured. The optic properties of the pyroxenes show considerable variation and both increases and decreases in optic axial angles from core to rim were found, although the longditudinal extinction angles generally showed an increase from core to rim; the following values were determined ($2V_z$ 65-71^o core to 67-79^o $_{rim}$, Z:c 33-62^o $_{core}$ to 38-64^o $_{rim}$). The crystal edges commonly show alteration to greenish aegerine-augite, which also forms slender inclusions in the alkali feldspar overgrowths. Iron ore (9%) forms some early idiomorphic crystals, but generally occurs in large laths and partly skeletal masses, up to 5 mm. long, intergrown with and moulding the other minerals, and poikilitically included in the alkali feldspar overgrowths. It appears to be titano-magnetite, or ilmenite, largely altered to leucoxene. Coarse apatite prisms are present reaching over 2 mm. in length. Patches of mesostasis (9%), resembling type 3, contain cores of analcime up to 1 mm. across, and rare olivine grains within the mesostasis are completely altered to serpentine.

Some of the bores through the basalt at Long Reach contain patches of coarse decomposed rock, up to at least 8 feet thick, particularly in the lower levels. A sample from D.D.H. 1 core, 50 feet below mean river level, in thin section 328 is a weathered pegmatite, with an abundant mesostasis (type 3) forming over half the rock.

Inclusions: Rare xenocrysts occur in the basalt and one of ~~the~~ alkali feldspar, about 1 cm. across, was noted in a sample from grid 8568E-2660N. In thin section 223, this xenocryst is fused and corroded along the borders, cracks and cleavages to a feldspathic glass, largely altered to sericite and zeolites. The fused border zone is up to 1.5 mm. wide and contains small prisms of colourless clino-pyroxene, indeterminate greenish brown material, and vughs lined with analcime and radiating fibrous overgrowth. The mineral in the overgrowth is zoned and length slow, with straight extinction and a low birefringence, and either represents a zeolite or released silica in the form of lussatite and chalcedony. The borders of the xenocryst~~s~~ are lined with a dense outgrowth of pale pink augite ($2V_z 61^{\circ}$; $Z:c\ 53^{\circ}$) forming prisms up to 1 mm. long (Plate 28).

The basalts in the Long Reach bores contain rare blocks of gritty sandstone up to a few inches across. Thin section 329 of such material from D.D.H. 1A core shows rounded quartz, clay, and rock fragments set in a dark brown isotropic matrix that becomes paler coloured along a thin contact zone with the decomposed host rock. These inclusions may represent xenoliths of Tertiary sediment, but they are not strongly indurated and alternatively may represent clastic dykes similar to those described previously.

Amygdale Minerals: Amygdales in the basalts are commonly lined with zeolites. In the quarry ½ mile north of Craigburn, the amygdales range up to about 3 inches across and either contain chabazite or trans-lucent, botryoidal and fibrous linings of thompsonite, sprinkled with small, whitish, radiating spherules of gyrolite. There is also rarer apophyllite and calcite, and some of the amygdales contain massive, whitish materials, apparently composed of mixtures of allophane, gibbsite or diaspore, clays, carbonates, zeolites, and possibly hydrated calcium silicates. Spherules of zoned, radiating fibres of gonnardite? are common in amygdales in the basalt elsewhere, but were not found at the Craigburn quarry.

Source and Nature of the Coarse Basalt.

The eruptive source of the coarse basalt is not obvious. Its general distribution and basal contours (Figure 6) suggest a possible source under the thick flow capping the area between Hillwood and East Arm, and the pegmatites about 1 mile north-west of Craigburn may mark the approximate position of a feeder. If the lava issued from here, then it spilled mainly to the south, north and west, pouring down into, and filling, the Tertiary Tamar channel. Alternatively, or in addition, lava may also have erupted in the bottom of the old Tamar valley, ascending possible faults along the lines of Long Reach, Moriarty Reach, and Whirlpool Reach, which controlled the general course of the Tertiary Tamar channel. The basalt extends to depths of 100 feet below present river level in these areas, and as its full downward extent has yet to be proved it may be within the throats of feeder channels. Whether the extrusion of the basalt occurred in one voluminous outflow, or whether a series of separate extrusions were involved, is difficult to determine from the available field evidence, as previously discussed. However, the existence of a flow of considerable thickness, can account for several of the following features.

The rocks show a consistently large grain size, even up against contacts with the underlying sediments, suggesting relatively slow cooling such as would take place in very thick lava columns. They show variations in modal mineralogy and chemical composition compatible with some differentiation in a thick lava column. Thus, in the vicinity of East Arm basalt at river level is picritic in nature, whereas outcrops at the higher levels are poorer in olivine and noticeably enriched in mesostasis; this suggests differential settling of olivine into a lower zone, and is discussed further at a later stage. The numerous pegmatites in the basalt indicate that there were considerable quantities of volatile-rich residual fluids within the lava; they occur at all levels, but are most abundant in the lower levels within the central channel. This suggests, either sufficiently slow cooling within the lower levels of a thick lava column to allow development and accumulation of the residual fluids, and/or the overwhelming of an old watercourse o f the Tamar with a sufficiently large volume of lava, so as to incorporate river water into the lava to form volatile-rich fluids, without causing any marked chilling or vesiculation by steam loss. It is perhaps significant in this regard that scoriaceous rock only develops in the relatively thin bodies intruding the under-lying sediments along the basalt contacts. Slow cooling and the accumulation of residual fluids in the lower levels of the lava column would also be likely within the throats of any underlying feeder channels, if these exist. Finally, thin sections of the basalts show close similarities in grain size, mineralogy, and textures to the rocks of Mt. Cameron West, N. W. Tasmania, which appears to represent a single extrusion over 400 feet thick (Sutherland and Corbett, 1967).

The central trough structure occupied by the basalt in the middle Tamar area (Figures 5 and 6) probably represents an old buried channel of the Tamar cut to well below present sea level, although the possibility that it is largely or in part an intrusive structure of elongate feeder channels must be kept in mind. An alternative possibility, that it represents a zone of major downwarping in the Tertiary rocks, subsequent to the extrusion of the volcanics, is unlikely, as, where observed, the underlying sediments along the contacts mostly dip away from the margins of the structure.

Influence on Drainage:

It is remarkable that the massive effusion of basalt does not appear to have caused any major lateral or upstream diversion of the Tamar River. This is possibly due to downsagging of the lava surface along the main channel filling, either from the concomitant slumping of the sediments along the channel margins, and/or from slow cooling within the thick central column allowing still fluid lava to drain away in this region. When the river, dammed upstream by lava, overtopped the barrier it would tend to follow any such downsags on the lava surface and thus become superimposed over the central basalt channel. Alternative explanations require the extrusion of a series of separate flows, shifting the course of the Tamar from one side of the valley to the other and finally back to the original position, for which there is as yet no direct evidence, or river capture along Moriarty Reach of one twin lateral stream by the other, which appears unlikely and still involves superimposition over the thickest zone of lava.

The course of the old Tamar at the time of the basalt extrusion, probably continued westwards at the north end of Long Reach, where it may have diverted around the older basalt flows in the lower Tamar area, as previously discussed.

Age.

The coarse basalt disconformably overlies dissected Middle-Upper Eocene sediments, the remnant of porphyritic basalt at East Arm correlated with the upper-olivine basalt in the lower Tamar area, the gravels north of Hillwood that contain pebbles of basalt identical to that of the lower olivine-basalt in the lower Tamar area, and, apparently, the lateritised surface of the olivine-nephelinite at Spring Bay. These facts suggest ~~that~~ considerable erosion of the lower Tamar basalts (post-Upper Eocene to Oligocene?) prior to the eruption of the coarse basalt. Lateritic soil profiles developed on the coarse basalt, resemble those of the Timboon Terrain in Victoria (Gill 1964), suggesting possible approximate correlation and hence a pre-Middle Pliocene upper age limit.

If the deep trough occupied by the coarse basalt represents an old channel of the Tamar, then it was presumably cut following tectonic uplifting and/or a major marine regression in Bass Strait. The available data on the Bass Strait area (Bock and Glennie, 1965; Esso Exploration Australia Inc., 1966; Sutherland and Corbett, 1967; Kershaw and Sutherland, unpublished manuscript) suggests that within the age limits under consideration such events occurred in the Upper Oligocene and in the Upper Miocene-Lower Pliocene. This indicates a late Oligocene-early Pliocene age limit for the coarse basalt, with the extensive subsequent dissection of these rocks perhaps favouring a late Oligocene-early Miocene age.

POST-BASALTIC SEDIMENTS.

Relatively unconsolidated deposits of clays and siliceous sands, grits and gravels, of probable Upper Cainozoic age, overlie the coarse basalts and the older Tertiary sediments. The most extensive occurrence caps the hillside above Deviot, at elevations of up to about 350 feet, but elsewhere such sediments generally occur at lower levels. Bore logs across Long Reach (Maunsell and Partners, 1962) record gravels and clays, up to 75 feet thick, overlying the coarse basalt and Lower Tertiary sediments to depths of over 140 feet below mean river level.

Fairly extensive lateritic profiles have developed over the coarse basalt, the olivine-nephelinite, and Tertiary sediments. These form undulating surfaces sloping from elevations of about 450 feet down to about 50 feet and tend to be presever in depressions, or fringe slopes, on the present land surface. The profiles carry boulders of nodular, pisolitic ferricrete, which may contain fragments of the underlying parent rock. Ferricrete boulders are particularly abundant on the olivine-nephelinite at Spring Bay (Plate 15), associated with reddish kraznosem soils. Some of the ferricretes on the coarse basalt, are associated with pallid, weathered zones, as seen about 3/4 mile north of Craigburn, and about 1 mile east of Whirlpool Reach. The age of these lateritic horizons is uncertain, but where they are associated with weathered and pallid lower zones, they resemble the Timboon Terrain in Victoria, dated as Lower Pliocene (Gill 1964). Where the nodular ferricrete is weakly developed, or not associated with any marked weathered lower profiles, as occurs on the Upper Cainozoic siliceous sediments in the area, it may represent semi-lateritisation such as developed under Pleistocene climatic conditions in

Victoria (Gibbons and Gill, 1964).

Talus and extensive landslip debris clothe many of the valley slopes within the area. These include dolerite pebbles shed from the sub-basaltic dolerite conglomerates, extensive float derived from the numerous basaltic outcrops, gravel and sand shed from the siliceous post-basaltic deposits, ferricrete fragments and "buckshot" ironstone gravels derived from the lateritic profiles, and deep soils on the Lower Tertiary sediments. Basaltic float is particularly extensive on the slopes north of Hillwood, and around Craigburn, Deviot, Spring Bay, Moriarty Reach, Long Reach and East Arm. Huge blocks, mapped as solid masses, occur just north of Craigburn, and include blocks up to 50 feet high and hundreds of feet across (Plate 16). These have moved by both forward toppling and backward rotational sliding, forming deep ravines or caverns between the blocks, and most of the large movements probably date back to times of active erosion in the Pleistocene.

UPPER TAMAR AREA. (Figures 9 and 10).

PRE-BASALTIC ROCKS.

Jurassic dolerite outcrops along the valley sides in this area bounded by faults with north-easterly downthrows. The western block is bounded by the Trevallyn Fault line, which appears to side-step eastwards in the vicinity of Rosevears, and again south of Blackwall. A wedge of sandstones and shales, of possible Triassic age, outcrops within the dolerite at this latter locality, updragged against the western contact and downdragged against the eastern contact. These contacts may represent lines of dolerite intrusion, but there is little obvious baking of the sediments. Slickensiding on the dolerite contact, in the road cut just north of Lanena roundabout, demonstrates at least some later movement, and the drags on the Triassic(?) sediments suggest it represents a downthrown block. Bauxite is developed on the dolerite in a few outcrops, in the vicinity of fault lines.

Clays and sands overlie the Jurassic dolerite in the central part of the valley. These beds are best exposed in the cliffs near Legana and the section here is described by Johnston (1874, 1888). Palynological dating of samples collected by the author from carbonaceous horizons in this exposure gave a Palaeocene age (W.K. Harris, pers. comm.) The beds are essentially horizontal to sub-horizontal, except where they are disturbed by landslips, and minor faulting, as in the underpass on the Upper West Tamar Highway above Strathlyn.

Basaltic rocks overlie the sediments on both banks of the Tamar. The oldest basalt in the area appears to be a small flow of olivine-basalt, confined to the west shore, and succeeded by a widespread and thick coarse olivine-basalt.

OLIVINE-BASALT.

This rock outcrops from an elevation of about 300 feet down to less than 50 feet above river level, on the hillslopes between Atkinstons and Muddy Creeks. Its occurrence is probably more extensive than as indicated on the map, but exposures tend to be obscured by extensive blankets of talus. The basalt reaches over 50 feet in thickness, and in places is strongly weathered to reddish soils associated with pisolitic ferricrete. It is dense, massive, dark bluish grey, and irregularly jointed.

Petrology.

In thin sections (15 slides, Figure 10) the rock consists of olivine phenocrysts in a fine grained groundmass of plagioclase, pyroxene, some olivine, iron ore and apatite, associated with a glassy and zeolitic mesostasis (Plate 30).

The olivine ($2V_z$ 87-103°, ≃ Fo 92-60) constitutes 17-26% of the rock forming corroded phenocrysts with a glomeroporphyritic tendency, ranging up to 1.9 mm. across. It is only slightly altered, and some of the crystals show strain polarisation. The plagioclase forms laths of labradorite ranging up to 0.7 mm. long with a composition of about Ab^{40}. Many of the laths show corroded interiors filled with a dark glassy residue, or inclusions of pyroxene and iron ore. The pyroxene (29-37%) is a zoned, purplish titan-augite ($2V_z$ $58°_{core}$ to $47°_{rim}$, Z:c $43\text{-}49°_{core}$ to $51\text{-}54°_{rim}$). It mostly forms small intergranular grains less than 0.1 mm. long, but in some sections there are sporadic microphenocrysts, in some cases forming rosette-like groups. Iron ore (5-11%) is scattered through the groundmass as squarish to irregular grains, rarely exceeding 0.2 mm. across. It is a titano-magnetite or ilmenite largely altered to leucoxene. Apatite (2-3%) forms numerous small needles within the mesostasis.

The mesostasis forms up to 28% of the rock as a glassy residue, clouded by small crystallites of iron ore, incipient analcimisation (?) and some slight chloritisation (?). Interstitial and amygdaloidal zeolites, include analcime, stilbite, and natrolite. In extreme cases (310) the mesostasis becomes strongly charged with iron ore and quite dark. Rare, irregular veinlets of mesostasis cut the rock (310) and a small sedimentary xenolith (?), largely replaced by prismatic clino-pyroxene ($2V_z$ 67° $_{core}$ to 58° $_{rim}$, Z:c 43° $_{core}$ to 51° $_{rim}$) was noted in section 243.

The rock resembles the Branxholm Type of Edwards (1950) and a chemical analysis (analysis 7, Table 1) shows it is an undersaturated basalt approaching a basanite in composition.

Source and Age.

The basalt appears to represent an extrusion of lava that flowed eastwards down towards the Tamar, from the vicinity of the Trevallyn Fault line. Its age can only be fixed within wide limits and it post dates dissection of the underlying Palaeocene sediments, but appears to disconformably underlie the coarse basalt (pre-Middle Pliocene).

COARSE OLIVINE-BASALT.

This rock occupies a dissected profile cut in the underlying Palaeocene sediments. It caps much of the area between Rosevears and Muddy Creek, and above Windermere, outcropping from elevations of 700 feet on the West Tamar and 500 feet on the East Tamar, down to below river level. The outcrops on the East and West Tamar were probably originally continuous, suggesting a maximum thickness of the order of 600 feet. Whether more than one flow is involved is uncertain, as field relationships between outcrops are obscured by deep dissection, widespread landslipping, and similar petrological characters. A thickness of over a hundred feet of basalt is exposed as a scarp above the southern slopes of Atkinsons Creek (Plate 16.)

Good exposures of the sediment/lava contacts are confined to the road cuts along the Upper West Tamar Highway, although these have deteriorated since the author first examined the freshly made cuts. A steep contact at Bradys Lookout, (Plate 17) dips about 70° to the south-west. The underlying sediments are strongly weathered and darkish over a couple of feet from the contact, and baking is slight with no marked chilling or vesiculation of the basalt margin. The contact probably represents the head of a small, steep sided, lava-filled valley. Chilling, vesiculation, and baking is slight at most of the basalt contacts exposed, except at grid 9189E-0633N, where there is a small patch of greyish chert hornfels.

The rocks are similar in appearance to the coarse basalts of the middle Tamar area. However, they become finer grained near contacts and pegmatitic phases are generally lacking, except for an occurrence on the plateau above Strathlyn. Sporadic, round amygdales occur towards the basalt margins and contain analcite, natrolite, stilbite(?) and other zeolites.

Jointing is similar to that in the coarse basalt in the middle Tamar area. Cooling columns on the southern side of Brady's Lookout curve downwards and outwards towards the steep basalt contact exposed in the road cut. ~~and then fan out upwards.~~ The orientation of cooling columns in the Brady's Lookout area is plotted in Figure 10, and in a number of cases the columns appear to have developed normal to the basalt base.

Petrology.

In thin sections the finer grained basalts of the contact zones (17 slides; Figure 10) resemble the olivine basalt previously described from the Strathlyn area. However, they tend to be a little more feldspathic, poorer in pyroxene, and to lack a cloudy mesostasis and corrosion of the feldspar laths. These finer grained phases grade into coarse basalt, and a few sections (386, 416) show intermediate porphyritic textures.

The coarse basalts (43 slides, Figure 10) are comparable in mineralogy and textures ~~to~~ with the coarse basalts described from the middle Tamar area, with similar variations in the type of mesostasis; the petrology of the rocks is summarised in Figure 10. Some sections (462, 465, 471), carry glomeroporphyritic phenocrysts of pale coloured augite with partly riddled interiors, and were restricted to samples collected from the western margin of the lava sheet above the upper West Tamar Highway. Pegmatite from grid 9312E-0715N, in thin section 385, closely resembles the pegmatites described from the middle Tamar area, with olivine ($2V_z$ 95-105°, $\simeq$ Fo 77-55) and sodian?titan- augite ($2V_z$ 77° core to 78° rim, Z:c 45-49° core to 52-58° rim).

In some places the coarse basalts grade up into more feldspathic varieties, correspondingly poorer in olivine. A chemical analysis of such rock (analysis 8, Table 1) shows a relatively high silica and alumina, and a low magnesia content, suggesting it may be a differentiated phase typical of the upper zone of the coarse basalt.

Source and Age.

No feeders for the coarse basalt are exposed. The presence of more strongly baked sediments at grid 9189E-0633N, in association with the appearance of augite phenocrysts in some of the rocks along the western margin of the lava field, suggests effusion along an apparent line of faulting in this vicinity (Figure 1). The lava field also reaches its highest elevation (699 feet) along this line south of the head of Atkinsons Creek, and a sample collected from the summit in thin section 461 was noticeably enriched in mesostasis. Contours on the base of the basalt (Figure 10) suggest that the lava spilled from this line mainly eastwards towards Strathlyn and northwards over the Brady's Lookout area, filling the ancestral Tamar channel and extending eastwards beyond Windermere. There is a possibility that the coarse basalt outcropping below the 300 feet elevation near Strathlyn, ~~that~~ the eastern part of the lava plateau above the 400 feet level south of Atkinsons Creek, and ~~that~~ the isolated cappings at the 400 feet level above Windermere, may represent separate and later flows. This part is marked off from the western outcrop by a topographic break (figure 10), and the pegmatite at grid 9312E-0715N, may mark a point of eruption as it is located over the Trevallyn Fault line and in the vicinity of the likely eruptive centre for the older olivine-basalt at Strathlyn.

The age of the coarse basalts cannot be fixed within narrow limits. They were erupted following considerable dissection and weathering of the underlying Lower Tertiary sediments, judging from their relative distributions (Figure 10) and from the nature of their contacts, as exposed at Brady's Lookout and elsewhere. The underlying olivine-basalt at Strathlyn also appears to have been weathered and dissected before the eruption of the coarse olivine-basalt. They closely resemble the coarse basalts of the middle Tamar area in occupying a channel cut to below present river level, and in the degree of subsequent dissection and development of lateritic soil profiles. This suggests approximate contemporaneity, and hence late Oligocene and Lower Pliocene age limits.

POST-BASALTIC SEDIMENTS.

Unconsolidated siliceous sands and gravels, similar to those described in the lower reaches of the Tamar, have been mapped to the north of Muddy Creek and on Native Point, where they form a well developed slip-off slope. They occur at various heights from river level up to elevations of about 50 feet, and represent deposits associated with both Recent and Pleistocene levels in the Tamar. A basalt breccia, at river level, 1 mile south of Rosevears, probably represents a Quaternary fluviatile deposit. Recent alluvium forms well developed tidal flats at Muddy Creek, Native Point and Nelson Creek.

Widespread basalt talus associated with extensive landslippage covers the valley slopes below the basalt cappings on both banks of the Tamar. The talus is composed of extremely large blocks below the basalt cliffs in the vicinity of Brady's Lookout, Gaunts Hill and at the head of Atkinson's Creek and Muddy Creek.

Some of the extensive landslippage associated with the downward movement of the talus probably dates back to the Pleistocene, and there are current active movements. Some ferruginous cementation of talus is seen in road cuts of the Upper West Tamar Highway south of Atkinson's Creek (grid 9165E - 0844N) and west of Brady's Lookout (grid 9010E-0971N; Plate 18) and suggests that these deposits are older than the typically uncemented talus, and are probably pre-Holocene, or even pre-Pleistocene, in age.

Reddish lateritic soils associated with underlying zones of strongly weathered basalt, and accompanied by fine sandy soils and fragments of pisolitic ferricrete, occur on the basalts above Strathlyn and Brady's Lookout. They resemble the lateritic profiles developed on the basaltic rocks in the middle Tamar area and debris derived from these profiles occurs among the basalt talus in a number of places.

SOUTH TAMAR AREA (Figures 11 and 12).

PRE-BASALTIC ROCKS.

The geology of this area is summarised in the mapping of Longman et.al. (1964, 1966) and Blake (1959), and compiled here in Figure 11, with additional details and modifications. Basalt flows overlie the Tertiary sediments in the southern part of the Tamar Trough in the vicinity of St. Leonards, White Hills, Breadalbane, Western Junction, Perth and Longford. The underlying sediments consist of clays, sands, lignites, doleritic and siliceous gravels, and lateritic horizons. They have been dated by palynological analysis as Plaeocene-Lower Eocene at Launceston and Rose Rivulet, and younger (post-Pebble Point and probably pre-Yallourn) in the vicinity of Evandale (Gill and Banks, 1956; Gill, 1962; W.K. Harris, pers. comm.). Small scale faults in the sediments north of Breadalbane (grid 0810E-8780N; Plate 20) were exposed during new road excavations in 1966, but now planted over. These dislocations reflect in miniature the south-westerly tilting and strike slip faulting of the Tamar Trough structure postulated by Longman et. al. (1964, 1965), but their precise age is unknown.

INTER-BASALTIC SEDIMENTS.

Dolerite conglomerates, associated with clays and sands, underlie the basalt in the vicinity of Rose

Rivulet, but contain rare fragments of weathered olivine-basalt indicating an inter-basaltic age. These beds extend from elevations of 750 feet down to 300 feet and appear to disconformably overlie the Palaeocene-Eocene beds. Blake (1959) mapped these beds as Pliocene boulder beds, but they may be considerably older than this. They resemble the basalt bearing dolerite conglomerate (Upper Eocene-Oligocene?) underlying the coarse basalt in the middle Tamar area, and the similar stratigraphic relationships suggest possible correlation.

Basalt boulders from the sub-basaltic conglomerate exposed under the coarse basalt above Sunnyside Farm (grid 1205E-8565N), in thin sections (204, 381) proved to be fine grained olivine- basalt composed of labradorite, intergranular colourless clino-pyroxene, and a little greyish mesostasis. The olivine phenocrysts are almost completely altered and amygdales are filled with chalcedony. Pebbles of similar basalt (sections 278, 279) were also collected from grid 1413E-8605N, but the precise relationships of this occurrence are more obscure. Petrologically this basalt resembles that forming a small isolated residual 3 miles E.S.E. of White Hills, suggesting derivation from that occurrence.

Scoriaceous basaltic tuffs are recorded underlying the basalt at Breadalbane in railway excavations (Johnston 1874, 1875, 1888), but these exposures are now largely covered. From the Fossil Cutting Johnston lists a coniferous forest flora overwhelmed in the tuff and from the Big Cutting he gives the following section in descending order.

"		ft.	Ins.
1)	Superficial chocolate soil	3	0
2)	Basalts, more or less consolidated and columnar underlain by tuffs more or less regularly stratified by water.	60	0
3)	Conglomerate, composed of waterworn fragments of basalt, mixed with waterworn siliceous pebbles.	4	0
4)	Series of beds of whitish clay and hard bands of greyish sandstone, full of leaf impressions.	30	0
5)	White and greyish arenaceous clays, becoming soft and soapy where permeated by water, and thus causing immense landslips along the slopes of the valley.	(Depth not (ascertained, (though supposed (to be 200-300 (feet deep."	

This section indicates that the "tuff" post dates the inter-basaltic conglomeratic beds of the area and pre-dates the coarse basalt at Breadalbane, possibly marking the initial phase of its eruption. However, in some places the base of the coarse basalt is strongly decomposed and granular in appearance, and the possibility that Johnston's horizon refers to this material, rather than a true tuff, must be borne in mind.

Detailed examination of the basalt outcrops in the South Tamar area has proved a number of seperate flows of different petrology.

SCORIACEOUS OLIVINE-BASALT.

This rock outcrops as a flow remant forming a small hill on the Blessington Road, 3 miles E.S.E. of White Hills, at an elevation from about 900 to 990 feet. The basalt overlies siliceous waterworn gravels and its base slopes down to the north-east. The capping is 60-70 feet thick and consists largely of scoriaceous basalt, strongly lateritised with a deep kaolinised and bauxitised lower profile and a more ferruginous upper crust.

Petrology.

Relatively fresh basalt only occurs at road level on the northern side of the outcrop and samples in thin sections (274, 378) show a vesicular rock containing olivine set in a groundmass of labradorite, augite, and iron ore, with a little greyish, partly glassy mesostasis.

The olivine forms 10-12% of the rock as corroded phenocrysts up to 1.3 mm. across. It is chrysolitic in composition and heavily altered around the crystal margins to reddish ferruginous material.

Plagioclase (37-43%) occurs as laths and anhedral plates of labradorite ranging up to 0.9 mm. in length and zoned from Ab38-Ab52. The pyroxene

(36-39%) is almost colourless augite, showing some zoning, and forming crystals up to 0.7 mm. across in an inter-granular to sub-ophitic inter-growth with the feldspar. Iron ore (5-7%) forms small squarish to irregular grains and lath-like rods, rarely exceeding 0.5 mm. long. The mesostasis (6-11%) is a colourless to pale greyish or brownish, glassy, feldspathic residue clouded with globules of iron ore.

Petrologically the rock resembles a near-~~under~~saturated olivine-basalt related to the Mersey Type of Edwards (1950), but the paucity of fresh rock exposure precluded accurate determinative sampling.

Source and Age.

The source for this flow is unknown, but the slope of its base suggests an origin to the west, providing there has not been later tectonic tilting from this direction. It appears to represent an old lateritised residual, younger than the Palaeocene-Eocene (?) beds, but probably older than the interbasaltic dolerite conglomerates that contain fragments of a similar basalt. The available evidence thus suggests an Eocene or Oligocene age.

THOLEIITIC OLIVINE-BASALT.

Remnants of this flow cap 7EX Hill above St. Leonards, overlying siliceous conglomerates and sands at an elevation of about 700 feet. The basalt is about 20-30 feet thick with a scoriaceous base passing up into more massive basalt. There is only slight baking of the underlying sediments and a petrological description of a contact sandstone rock is given in Longman *et.al.* (1966).

Petrology.

In thin sections (6 slides) several variations can be recognised. The massive basalt (173) consists of olivine and plagioclase set in an abundant hyaloophitic, black glassy mesostasis (Plate 32). The olivine ($2V_z$ 88-99^o, $\simeq$ Fo 91-67) forms 13% of the rock as deeply corroded glomeroporphyritic fresh phenocrysts up to 1.8 mm. across, and scattered groups of small granules. The plagioclase (38-43%; composition about Ab40) forms skeletal laths and plates reaching up to 1.2 mm. but rarely exceeding 1 mm. The remainder of the rock is made up of the opaque glass containing numerous elongate crystallites of plagioclase and pyroxene, commonly as radiating sheaves, and a little greenish yellow opal and chalcedony. This rock matches and Ouse Type of Edwards (1950) and McDougall (1959) and grades into a slightly more vesiculated rock. In this variety (208) the olivine phenocrysts reach up to 2.3 mm. across and show a little alteration to opal and carbonate, while the labradorite laths rarely exceed 0.3 mm. in length. Small intergranular grains of pale coloured augite (19-23%, Z:c 44° $_{core}$ to 46° $_{rim}$) have crystallised in the black glassy mesostasis (25%). Vesicles tend to be filled with opal, chalcedony and carbonate, and the rock is related to the Bridgewater and Pontville types of McDougall (1959). Strongly vesicular varieties (172, 420) are similar, but the black glass has largely crystallised giving rocks with olivine (12%), zoned labradorite (39-44%) and intergranular to sub-ophitic augite, with rare pigeonite (?), (32-37%). Iron ore (4-6%) forms small irregular grains and laths, and the mesostasis (4-9%) is brownish grey and clouded with crystallites. This variety approaches the Jordan Type of McDougall (1959).

Source and Age.

The position of the feeder for this flow is uncertain. A small patch of basalt has been mapped to the west on the lower slopes of 7EX Hill, just above St. Leonards township (Longman et.al., 1964). This basalt was exposed during an excavation for a private swimming pool several years ago (Dr. K. Burns, pers. comm.) The excavation went down through soil, clay, then into weathered basalt with fairly regularly shaped joint blocks. At about 9 feet in depth, the excavation passed into clay containing large fossilised tree trunks replaced by ironstone. No trace of basalt is now visible at the site and its precise relationship to the 7EX Hill flow cannot be determined. However, the restricted nature of the occurrence and its position makes it a possible feeder neck for the 7EX Hill flow. The flow overlies the Palaeocene-Eocene beds, but other field evidence as to its age is lacking.

LIMBURGITE.

This rock forms small cappings above the "Duneiden" farm houses, less than a mile to the south-west of the 7EX Hill flow at the same elevation of 700 feet. The flow is up to about 20 feet thick, becomes moderately vesicular near its base, and outcrops in a similar fashion to the 7EX Hill flow.

Petrology.

The rock is dark and fine grained and in thin sections (206, 207) consists of olivine, clino-pyroxene, and iron ore, set in a darkish glass.

The olivine ($2V_z$ 88-99°, $\cong$ Fo 91-67) forms 14-19% of the rock as fresh corroded phenocrysts up to 2 mm., but generally smaller than 1 mm. across, and some of the crystals show strain polarisation and translation lamellae.

The clino-pyroxene (37-42%) forms zoned, prismatic crystals up to 0.5 mm. long, and is mostly augite (Z:c 44-49° $_{core}$ to 49-55° $_{rim}$) with a faint brown or purple and pleochroic tinge, on the crystal margins. The rest of the rock is a hyaloophitic to hyalopilitic purplish brown glass, containing small, squarish grains and lath-like crystallites of iron ore, rarely exceeding 0.1 mm. across, sporadic patches of pale yellowish opal, and vesicles lined with opal and carbonate.

A chemical analysis (analysis 17, Table 1) shows that it is a strongly undersaturated rock relatively low in alumina and alkalies.

Source and Age.

The flow overlies the Palaeocene-Eocene beds, but there is little other field evidence as to its age. Its source is also uncertain, but its close association and similarity in outcrop to the 7EX Hill flow suggests possible eruption from a related centre.

OLIVINE-NEPHELINITE.

This rock forms a small flow overlying Jurassic dolerite and Tertiary sediments, about 3 miles north-east of St. Leonards, at an elevation of about 900 feet. The flow is between 20-30 feet thick and bears remnants of a lateritised surface. It contains small xenoliths of Jurassic dolerite and rare peridotite nodules in the road cut on the Scottsdale Highway.

Petrology.

The rock is dense, bluish grey, and fine grained, and xenoliths, xenocrysts, and amygdales tend to stand out on the weathered surface. In thin sections (6 slides) the rock consists of olivine phenocrysts in a groundmass of olivine, clino-pyroxene and iron ore, with a glassy, feldspathoidal mesostasis, and some sections contain rare dolerite xenoliths and pyroxene xenocrysts.

The olivine ($2V_z$ 86-97,≏ Fo 94-74) forms 13-18% of the rock, and is generally fresh, but shows some alteration along cracks to greenish or yellowish brown chloritic or "bowlingitic" (?) materials. The phenocrysts reach up to 2.5 mm. across and are generally corroded, except for some small euhedral crystals; some show strain polarisation and translation lamellae. The dolerite xenoliths reach up to 5 cm. across and show a mineralogy and texture typical of the Jurassic dolerite bedrock in the area, although the mesostasis appears to have been fused to a pale yellowish or dark brown glass.

The clino-pyroxene (37-46%) occurs as grains and prismatic microphenocrysts of titan-augite up to 0.7 mm. in length and noticeably pleochroic from brownish yellow to violet. Rare, corroded clino-pyroxene xenocrysts, apparently derived from the dolerite xenoliths, and pyroxene exposed on the margins of the dolerite xenoliths, are rimmed with overgrowths of titan-augite. Iron ore (7-10%) is dispersed through the rock as numerous minute squarish to irregular grains less than 0.5 mm. across and is a titano-magnetite or ilmenite, largely altered to leucoxene. There are also rare larger clots of iron ore up to 2 mm. across. In section 211 one of these has a core of brownish green spinel, indicating that the clots probably represent altered spinel xenocrysts. Apatite (2-3%) forms elongate prisms up to 0.5 mm. long and minute needles in the mesostasis.

The feldspathoidal mesostasis (14-25%) is a hyalopilitic glass slightly clouded in places with crystallites of iron ore, and contains poikilitic areas of nepheline up to 2 mm. across. Amygdales are mostly lined with natrolite, and the margins of some of the dolerite xenoliths (339) contain pockets of natrolite and euhedral skeletal crystals of nepheline, up to 0.5 mm. long, filled with a darkish glass.

This rock is similar in its petrology to some sections of the olivine-nephelinite near Spring Bay in the Middle Tamar area, and probably has a chemical composition closely similar to that of analysis 16, Table 1.

Source and Age.

The eruptive point for this flow is probably marked by the presence of the dolerite xenoliths in the cutting on the Scottsdale Highway. This point also lies on the projected intersection of a north-westerly and a north-easterly fault or strong joint lineament mapped in the near vicinity (Longman <u>et.al.</u>, 1964).

The flow appears to overlie sediments that probably represent an extension of the Palaeocene-Eocene beds of the Tamar Trough. It appears to have been lateritised, and is thus probably pre-Middle Pliocene in age, but further field evidence as to its age is lacking.

OLIVINE-PYROXENE-BASALT.

A small outcrop of this rock occurs within Tertiary sediments at an alevation of about between 100-130 feet on the east bank of the North Esk, 1½ miles north-east of Corra Linn bridge. The basalt is massive and contains numerous inclusions,which project on the weathered surface giving it a rough appearance. Inclined cooling columns are developed normal to the base of the basalt which dips down toward the river.

Petrology.

The rock is a darkish grey and speckled with the numerous inclusions. These include fragments of dolerite up to several inches across, some with small irregular veinlets of fused glassy material on the outer margins; crystals of black vitreous pyroxene up to a few cms. across, many with marked border zones; and rare small peridotite nodules.

In thin sections (9 slides) the rock contains xenoliths of dolerite, rare small bodies of partially replaced glassy material, peridotite nodules, and abundant xenocrysts, phenocrysts and microphenocrysts of olivine, augite, and spinel. These are set in a groundmass of olivine grains, plagioclase laths, some granular iron ore, and a fairly abundant hyaloophitic to intersertal, darkish, cloudy mesostasis (Plate 33).

The dolerite xenoliths show a mineralogy and texture typical of the Jurassic dolerite bedrock of the area, but appear to have undergone partial melting on incorporation into the basalt and the normal mesostasis has been largely fused to a glass. In sections of the dolerite, (563, 564; Plate 34) pyroxene and feldspar crystals in contact with the mesostasis tend to be corroded and many of the pyroxenes show fritted, minutely riddled margins. Whispy and sheaf-like fibrous masses, both within the mesostasis and as overgrowths on some of the pyroxene crystals, appear to represent incipient crystallisation of orthopyroxene, some clino-pyroxene, and some sillimanite or mullite (?). The mesostasis also contains remnant crystallites of feldspar and iron ore and is strongly charged with granular iron ore, passing into an opaque blackish

glass. Some small euhedral and skeletal tablets of alkali feldspar (sanadine ?) are present in a few places, and in section 563 there are patches of chalcedony, partly fringed by lussatite (?). These show a structure reminiscent of the curved fracture of cristobalite and may represent an alteration of this mineral. The dark mesostasis passes into clear to pale yellow or brown, partly devitrified, feldspathic glass, formed around the fused (?) ends of some plagioclase laths.
Small, elongate prisms of colourless clino-pyroxene have crystallised in some of this clear glass. Sporadic amygdales within the mesostasis are filled with analcime, natrolite, and other zeolites.

The rare, small, glassy bodies scattered through the basalt probably represent fused xenoliths of Tertiary sediment. They range up to 2 mm. across and consist of brownish or colourless glass bordered and replaced by granular to prismatic clino-pyroxene.
The rare peridotite nodules (562) consist of anhedral olivine ($2V_Z$ 86-97, $\simeq$ Fo 94-74) up to 3 mm. across, associated with colourless clino-pyroxene ($2V_Z$ 63-66; Z:c 48-50), and a little plagioclase (about Ab37).
The olivine shows translation lamellae, and where the pyroxene is in contact with the host rock it is resorbed and in parts mantled with an overgrowth of zoned titan-iferous augite.

Augite xenocrysts form 4-11% of the rock, ranging from about 0.5 mm. up to over a cm. across, but mostly within 1 to 5 mm. across. The larger xenocrysts, contain corroded cores of colourless augite ($2V_z$ 50-56°, Z:c 47-49°) surrounded by borders of resorbed spongy augite ($2V_z$ 50-62°, Z:c 44-52°), more or less optically continuous with the core. These borders reach up to about 2 mm. in width, contain small inclusions of corroded olivine, a few trains of fresh clinopyroxene, and in some cases show a rough concentric layering due to differing degrees of resorption. In the smaller xenocrysts the core is generally completely resorbed. Each xenocryst is mantled with an euhedral to subhedral overgrowth of zoned titan-iferous augite, up to 0.4 mm. wide. Several narrow zones, some oscillatory, may be present and there is a general change from colourless augite on the inner margin to coloured titan-augite on the outer margin, pleochroic from brownish yellow to violet. Cleavages tend to be continuous across the overgrowth and the inner xenocryst. Some of the overgrowths show a little corrosion riddling and the augite tends to build out in prismatic extensions. A few clino-pyroxene xenocrysts, showing slight chloritisation, are scattered through the rock and appear to represent isolated crystals derived from the xenoliths of Jurassic dolerite. A few plagioclase xenocrysts, presumably similarly derived, show fused glassy borders partially replaced by small prisms of colourless clino-pyroxene. Rare anhedral xenocrysts, up to 8 mm. across, of grey, brown and olive-green spinel, are altered along their margins to opaque iron ore. Sparse, largish clots of iron ore in the rock may represent completely altered spinel xenocrysts, and in some cases these are outgrown with titaniferous augite.

Olivine ($2V_z$ 86-99°, ≃ Fo 94-67) forms 11-17% of the rock as corroded phenocrysts, some with inclusions of iron ore, reaching up to 3.5 mm. across and grading down to small granules less than 0.05 mm.. Some of the larger crystals show strain polarisation and translation lamellae, indicating derivation from the peridotite nodules.

Plagioclase (24-35%) forms laths and zoned plates up to 1.5 mm., but mostly less than 1 mm. in length. The laths have a composition of about Ab35 and show Carlsbad, Albite, and Pericline twinning. Some have slightly hollowed interiors and the larger laths show slight flow alignment. The titaniferous augite represented in the xenocrystal overgrowths forms 26-31% of the rock as glomeroporphyritic euhedral to subhedral microphenocrysts (mostly between 0.3 to 0.5 mm. across, commonly in rosettes) grading into smaller ground mass grains, and as rare, larger, corroded phenocrysts up to 2 mm. across, containing inclusions of the groundmass minerals. This augite commonly show lamellar twinning, hour glass structure and colour zoning, generally with more intensley coloured and pleochroic outer zones (X brownish yellow, Y Z violet). Optically, the crystals commonly show an increase outwards of $2V_Z 54-66^o$ (core) to $65-72^o$ (rim), and Z:c $45-54^o$ (core) to $54-61^o$ (rim), but crystals with paler outer zones, and some of the groundmass grains show a decrease outwards of $2V_Z 59-66^o$ (core) to $41-53^o$ (rim) and Z:c $47-49^o$ (core) to $41-42^o$ (rim). Small, squarish to irregular grains of iron ore (4-6%) are dispersed through the rock and rarely exceed 0.05 mm. in size.

The mesostasis (12-23%) is glassy, darkened with numerous crystallites of iron ore, and contains sporadic patches of calcite and zeolites. Plates of late-stage feldspar in the mesostasis enclose small needles of clino-pyroxene and apatite and are intergrown with crystallites along their margins.

Chemically (analysis 9, Table 1), the basalt is strongly undersaturated with a relatively high lime and magnesia and slightly low alkali content, presumably reflecting the abundance of augite xenocrysts. Analyses of the augite in the xenocryst cores, recrystallised reaction rims and new overgrowths, show that the cores have high alumina and soda and relatively low calcium compared ~~to~~ with the reaction rims and overgrowths (D.H. Green and N. Gray, pers. comm.; analyses 1-4, Table 2). This is consistent with crystallisation of the xenocrystal augite from the basalt magma at high pressure at depth (D.H. Green, pers. comm.). The analyses also show correlation between increase in titanium content and violet colouration of the overgrowths, compared with the colourless xenocrystal cores and reaction rims.

Source and Age.

The basalt appears to represent a small neck containing abundant xenoliths of country rock, with peridotitic nodules and xenocrysts brought up from depth. The petrological similarity of the host basalt, to the olivine-basalt flow east of Rose Rivulet, makes it a possible feeder for that basalt.

The Corra Linn basalt appears to post-date the adjacent Palaeocene-Eocene beds, but further direct field evidence of its age is absent. The isolation of the neck indicates considerable post-eruptive erosion, and if it represents a feeder for the olivine-basalt flow to the south, then correlation suggests a probable Oligocene or Miocene age (see later).

OLIVINE-BASALT.

Several isolated outcrops of this rock occur south of White Hills and east of Rose Rivulet, apparently representing dissected remnants of a single flow. The base of the basalt (Figure 12) descends from an elevation of about 750 feet on its eastern margin, down to about 200 feet near Talisker Farm, where the basalt reaches its maximum exposed thickness of about 100 feet. The basalt overlies the inter-basaltic conglomeratic beds resting on the Palaeocene - Eocene sediments, and fills a dissected profile in the underlying sediments. Quarrying above Talisker Farm has exposed a basalt/sediment contact sloping steeply down to the west, and there is slight baking with darkening of the sediments up to a few inches from the contact.

The basalt is generally massive, but in places carries sporadic amygdales commonly filled with zeolites, including natrolite. Well developed cooling columns with moderately to shallow inclinations are exposed in the quarry at Talisker Farm and at one point these form "synclinal" structure.

A deeply weathered profile has developed on basalt at grid 1580E-8650N, and although no fresh basalt remains, it appears to represent a lateritised remnant of this flow. It occurs at an elevation of about 750 feet and forms part of the Woodstock B surface of

Nicolls (1960).

Petrology.

In thin sections (19 slides) the basalt consists of phenocrystic olivine and clino-pyroxene in a groundmass of plagioclase, clino-pyroxene, iron ore, a little olivine, and a glassy mesostasis.

Olivine forms 16-24% of the rock as slightly glomeroporphyritic, commonly corroded phenocrysts, up to 2 mm. across, but mostly less than 1 mm, and grades down to small sporadic grains in the groundmass. Titaniferous augite (28-37%) forms strongly glomeroporphyritic, subhedral to euhedral phenocrysts and microphenocrysts, up to 1.2 mm. across with a tendency to form rosettes, and also occurs in numerous, small intergranular grains. The augite shows lamellar twinning, hour glass structure, colour zoning, with brownish yellow to violet pleochroism, and Z:c $44-50^{\circ}$ (core) to $54-48^{\circ}$ (rim). Plagioclase (30-43%) forms laths of labradorite (composition about Ab36) and zoned anhedral plates, ranging up to about 1 mm. in length, showing some flow alignment. Iron ore (4-8%) is dispersed through the groundmass as small squarish to irregular grains, mostly less than 0.1 mm. across, or as lath-like crystallites in the mesostasis. Apatite (2%) forms numerous needles in the late-stage feldspar and the mesostasis.

The mesostasis forms up to 20% of the rock as an intersertal to almost hyalopilitic, glassy, residue, generally clouded with crystallites. In some sections (195, 201, 202, 218, 280, 283) it has largely crystallised to late stage alkali(?) feldspar and interstial zeolites, including analcime, accompanied by a little nepheline(?) and biotite; but in others (212, 280, 288, 380) it tends to pass into a brownish glass. Sporadic amygdales contain zeolites, calcite, and a little greenish clay or chalcedony. Small xenoliths of Tertiary (?) sediment occur in a few sections (283, 291, 296) and are commonly fused to a clear or brownish glass, partly replaced with prismatic, colourless clino-pyroxene. Some of the xenoliths develop envelopes of brownish glass interspersed within the host rock. A pyroxene xenocryst, 4 mm. across, was noted in section 372 and consists largely of resorbed material replaced with exsolved plates of colourless augite ($2V_z$ 56 $_{core}$ to 53^{o} $_{rim}$) and partly mantled with an overgrowth of titaniferous augite ($2V_z 51^{o}$ inner rim to 56^{o} outer rim).

This rock resembles the Corra Linn rock, but lacks the numerous pyroxene xenocrysts, and also resembles the olivine-basalt at Strathlyn in the upper Tamar area.

Chemical analyses of the rock show that it is an under-saturated basalt, approaching a basanite in composition (analyses 10 and 11, Table 1). The dark, glassy mesostasis-rich variety (analysis 11) is slightly enriched in iron and soda at the expense of alumina, lime and potash, compared with ~~to~~ the more typical rock (analysis 10).

Source and Age.

The basalt appears to have flowed into a small, steep valley, near Talisker Farm, but its precise source is uncertain. It may only represent an extension of the coarse basalt flow erupted from Cocked Hat Hill, as discussed later, but at Currachmore Farm its highest point slightly exceeds the elevation of Cocked Hat Hill suggesting a separate eruption flowing westwards down from the vicinity of Currachmore Farm. Alternatively, the neck at Corra Linn may have been the feeder, with the lava flowing southwards towards Currachmore Farm and thence westward down to Talisker Farm.

The basalt post-dates the dissection of the underlying interbasaltic conglomeratic beds which overly the Palaeocene-Eocene sediments. The apparent deep weathering and lateritisation of the basalt at grid 1580E-8650N, suggests a pre-Middle Pliocene age, based on the arguments of Nicolls (1960) and the dating of similar lateritic profiles in Victoria (Gill, 1964).

Within these limits the most likely times at which the deep dissection of the underlying beds took place appear to be in the Upper Oligocene and in the Upper Miocene-Lower Pliocene, based on the known history of Bass Strait and northern Tasmania (Esso Exploration Australia Inc., 1966; Sutherland and Corbett, 1967; Kershaw and Sutherland, unpublished manuscript). If the source of the basalt was the Corra Linn neck, then there has been considerable subsequent erosion suggesting an age approaching the older limit, (late Oligocene-Miocene) and comparable with the likely ages of petrologically similar lavas in the middle and upper Tamar areas.

COARSE OLIVINE-BASALT.

This rock outcrops west of Rose Rivulet from Breadalbane to Evandale and in isolated exposures in the Perth-Longford area. It disconformably overlies the inter-basaltic conglemeratic beds and underlying Palaeocene-Eocene sediments at grid 1205E-8565N, in a similar manner to the basalt east of Rose Rivulet. It is partly buried by Upper Cainozoic siliceous sands and gravels, referred to as the Brickendon Gravels by Nicolls (1960)

The base of the flow overlaps on to Jurassic dolerite bedrock on its western margin at elevations between 500-630 feet and descends in places to 300 to 350 feet on its eastern margin. The highest point on the flow forms Cocked Hat Hill at an elevation of 725 feet, indicating a maximum flow thickness of at least 200 feet and probably more than 400 feet.

The basalt is massive, develops cooling columns in places, and is deeply weathered in parts. Sporadic amygdales occur and in a small excavation just below Mt. Oriel Farm contain natrolite.

Petrology.

In thin sections (17 slides, ~~Figure 12~~) most of the rocks are medium grained and closely comparable in modal mineralogy with the coarse basalts described from the middle and upper Tamar areas, but marked picritic and pegmatitic phases were not noted. The pyroxene in the rocks is predominantly intergranular with little development of sub-ophitic to ophitic textures, and the mesostasis is mostly type 2 or 3. The coarsest rock (213) forms the summit of Cocked Hat Hill and is a feldspathic, olivine-poor variety compared with ~~to~~ some of the rocks at lower levels, suggesting that it may represent an upper differentiated zone. Towards the base the basalt passes into a finer grained rock (165, 216, 300, 578, 579) petrologically identical to the basalt east of Rose Rivulet, but in some places a medium grain size is maintained almost up to the basal contact. Petterd (1902) gives a microscopic description of a hydrated olivine-basalt, resembling palagonite, found in sinking holes at Native Point, Perth, but the precise relationships of this rock to the nearby coarse basalt is uncertain.

Source and Age.

Johnston (1888) considered that the eminence of Cocked Hat Hill formed the principle eruptive vent for the Breadalbane flow, and a recent regional gravity survey indicated the existence of a large dyke extending to depth below Cocked Hat Hill (M.J. Longman and D.E. Leaman, pers. comm.). The eruption of thick lava from Cocked Hat Hill may have blocked the Tamar at Evandale, diverting it through Longford and via the gorge to Launceston, forming the present course of the South Esk, (Carey, 1946). However, the fact the much of the lava extends upstream from the eruptive point, apparently against the drainage, may mean that the Tamar had already been diverted through Longford by one of the earlier flows, prior to eruption of the coarse basalt and perhaps considerably earlier.

Some petrological similarities between the coarse basalt and the basalt east of Rose Rivulet suggests the possibility that the two occurrences may be dissected parts of a single flow, with the coarse basalt resulting from slower cooling of the lava where it accumulated to a considerable thickness in the main channel of the ancestral drainage. Critical to this interpretation is the position and age of the conglomerate exposed in the railway cutting $1\frac{1}{4}$ miles due north of Western Junction station. The conglomerate appears near the base of the flow, but its contacts are not clearly exposed. The deposit is at least 6 feet thick, shows some degree of consolidation, and includes worn fragments of basalt, Jurassic dolerite, and quartzite, up to boulder size and showing some imbrication. The basalt fragments in thin sections (194, 576) are petrologically similar to the basalt east of Rose Rivulet. An underlying position for the conglomerate would indicate that the coarse basalt post-dates the basalt east of Rose Rivulet with an intervening period of erosion. In this case the lack of evident lateritisation of the coarse basalt allows an upper age limit for it as young as Pleistocene (Gill and Banks, 1956; Nicolls, 1960). However, the degree of weathering and the presence of basalt pebbles in sediments of probable Tertiary age at Perth (discussed below) suggests that the coarse basalt is likely to be pre-Pleistocene and perhaps approximately comparable in age to the coarse basalts in the middle and upper Tamar areas.

POST-BASALTIC SEDIMENTS.

Clays and gravels of probable Tertiary age have been drilled near Perth Railway Station to depths of 50 feet (Jennings, 1965). The gravels include numerous basalt pebbles in many of the horizons, and their proximity to the coarse basalt outcropping at Perth suggests that the sediments post-date the flow and are probably fluviatile deposits of the South Esk.

Siliceous gravels, sands, and clays of Upper Cainozoic age (Brickendon Gravels) form an extensive veneer in the Evandale-Perth-Longford area (Blake, 1959; Nicolls, 1960). These reach a maximum thickness of at least 30 feet, but are generally less than 20 feet, and in places bury the flow of coarse basalt. Their precise age is uncertain, but they appear to be younger than the beds drilled at Perth station.

Lateritic soils are developed across Jurassic dolerite, and the Tertiary sediments and basalts, as remnants of the Woodstock surface, regarded as probably Pliocene in age (Nicolls, 1960). Nodular ironstone soils also occur in the Brickendon gravels in places and may have developed during Pleistocene interglacials (Nicolls, 1960).

Other Quaternary deposits in the area include wind blown sands around Perth and Longford, basalt talus and landslip debris along the valley slopes of Rose Rivulet and the North and South Esk, and recent alluvium associated with this drainage. The terrace systems associated with the Quaternary deposits and their relationships to the drainage are discussed in detail by Nicolls (1960).

RELATIONSHIPS OF THE TAMAR TROUGH VOLCANIC ROCKS TO THOSE IN ADJACENT AREAS.

Preliminary investigations of the Tertiary volcanic rocks have been made in several areas adjacent to the Tamar Trough for a comparative study.

NORTH-WESTERN AREA. (Dulverton - Moriarty - Thirlstane area).

The regional distribution and stratigraphy of the Tertiary volcanic rocks in this area have been mapped by Burns et.al. (1963, 1964) and Jennings et.al. (1959). Two separate basalt horizons are mapped. The older Thirlstane Basalt occupies a deep valley cut in the Harford Beds, which lithologically resemble the Lower Tertiary beds in the Tamar Trough. The Thirlstane Basalt is overlain by, and interbedded with, the Wesley Vale Sand and its correlates. At Parkers Ford lignitic clay overlying basalt has been dated as probably Upper Oligocene in age, while the top part of the Wesley Vale Sand probably correlates with the Lower Miocene high sea-level stand in Tasmania. The Wesley Vale Sand is overlain by the Moriarty Basalt, which has been deeply weathered and lateritised, probably during the Pliocene.

Thin sections of samples collected from the Thirlstane Basalt by the writer, or taken from Tasmanian Mines Department cores, show two main petrological groups. The first includes the basalt from below the Upper Oligocene (?) sediments at Parkers Ford, (353, 499), from

Ilse's Bore (516, 517), Parson's Bore (519), the 585 ft. depth below the new Board Mill site at Wesley Vale (521), and south-west of Moriarty (400,402). These basalts resemble the Mersey Type of Edwards (1950) and the lower olivine-basalt in the lower Tamar area. In some cases, however, the sections carry sporadic phenocrysts of plagioclase and grade into the Waratah type (Edwards, 1950). Section 517 from Ilse's Bore is strongly porphyritic with large plagioclase and pyroxene phenocrysts which may indicate proximity to an eruptive vent. The second group includes the basalts at Moorland Point (351), east of Moriarty (349, 350) and interbedded with the Wesley Vale Sand at Wesley Vale (513, 514). These grade from types resembling the upper olivine-basalt in the lower Tamar area to types approaching the Branxholm Type of Edwards (1950) and the titan-augite basalts of the Tamar Trough.

The Moriarty Basalt (354, 352) resembles the undersaturated titan-augite basalts of the Tamar Trough, and similar rocks form the basalt dyke along the western part of the Dulverton Fault line (398, 399, 401, 403).

Although further detailed work is necessary, the following sequence of volcanism is tentatively suggested ~~in~~ for this area.

1) The eruption, prior to the Upper Oligocene, of olivine-basalts, from possible centres near Ilse's Bore and the eastern end of the Dulverton Fault line, filling valleys cut in the Lower Tertiary (?) Harford Beds.

2) The eruption of undersaturated titan-augite olivine-basalts during the deposition of the lower part of the Wesley Vale Sand in the Upper Oligocene.

3) The eruption of undersaturated titan-augite olivine-basalts, from the western part of the Dulverton Fault line, into shallow valleys cut in the Wesley Vale Sand, in post-Upper Oligocene and pre-Lower Pliocene time.

This eruptive succession is of interest in its similarities with that determined for parts of the Tamar Trough.

<u>SOUTH WESTERN AREA:</u> (Deloraine - Westbury - Selbourne - Hagley - Glenore area).

Almost all the basalts examined from this area are types related to the titan-augite olivine-basalts and coarse basalts of the Tamar Trough. The basalts (359, 362, 364, 374, 377) include some with glomero-porphyritic augite and some showing corrosion of plagioclase laths, as in the upper and south Tamar rocks. The coarse basalts (355, 356, 357, 358, 363, 373) commonly carry large glomeroporphyritic phenocrysts of augite to a greater extent than noted in the Tamar

Trough rocks. Edwards, (1950) also records rocks of the Mersey, Waratah, and Midlands Types in the area. Thus the eruptions in this area appear to have much in common with those of the Tamar Trough.

SOUTHERN AREA: (Nile - Campbell Town - Avoca - Blessington area).

This area is mapped by Nye (1926) and Blake (1959). Petrological studies by Edwards (1950) show that the basalts around Nile and Campbell Town are mostly tholeiitic olivine-basalts with some outcrops of oligoclase basalt and the Mersey Type. Tholeiitic olivine-basalts also were collected by the writer in the Conara-Avoca area (494, 498, 531). Edwards records a limburgite from Lewellyn, west of Avoca, and samples collected by the writer grade toward olivine-nephelinites (539, 540). An isolated basalt hill near Blessington is an olivine-basalt carrying large xenocrysts of clino-pyroxene with well developed reaction coronas (219). It appears to represent an eroded plug with xenocrysts from depth, similar to the outcrop north of Corra Linn in the south Tamar area. Thus, this area shows a similar range of basaltic types as found in the south Tamar area, but differs in that tholeiitic olivine-basalts greatly predominate over the undersaturated olivine-basalts.

EASTERN AREA: (Watery Plains - Bullocks Hunting Ground-Porssers Forest - Nunamara - Myrtle Bank -

-Patersonia - Georges Plains area.

This area is mapped by Longman et.al. (1964, 1966) and on examination all the basalts proved to be tholeiitic olivine-basalts resembling the Bridgewater and Midlands Types of Edwards (258, 259, 260, 262, 263, 264, 376). Thus, this area differs greatly from the Tamar Trough, where such rocks are confined to the small flow at 7EX Hill. Further east at the Sidling a flow of olivine-nephelinite with numerous large peridotite nodules (162) forms a high level residual relative to the tholeiitic olivine-basalt flows occupying the lower valley areas. This relationship may have some bearing on the relative ages, as yet unknown, of the olivine-nephelinite and the tholeiitic olivine basalt in the south Tamar Trough.

NORTH-EASTERN AREA: (Lefroy - East Tamar Heads area).

The geology of the Lefroy area and petrological descriptions of the Tertiary basalts are given by Groves (1965), and the thin sections quoted have been examined by the present writer. The Lefroy rocks resemble the upper-basalt in the lower Tamar area in regard to the type of mesostasis and the presence of late stage silica and carbonate, but they show a coarser, ophitic texture, while the pyroxene is slightly more deeply coloured and presumably titaniferous. The coarse, pegmatitic variety from near the head of the flow at Lefroy may indicate the position of the eruptive vent. Basalt from the coastal outcrop 2 miles east of Low Head (255) is petrologically similar to that forming the lower-basalt in the lower Tamar area and indeed may represent an eastward extension of the same flow. Thus, the eruptions in this area resemble the lavas of the lower Tamar area and may be similar in age.

SUMMARY AND DISCUSSION.

MINERALOGY AND ORDER OF CRYSTALLISATION IN THE TAMAR LAVAS.

Determination of Mineral Compositions.

Compositions of the main minerals crystallising in the Tamar lavas were gauged by the following methods. Optic axial angles of olivines and pyroxenes were determined on a Leitz four-axis universal stage. Difficulties in determining olivine compositions from 2V measurement (Wylie, 1959; Munro, 1966) are applicable to the data presented in this study, but clearly aberrant values have been omitted and errors in the $2V_Z$ values are probably not significantly greater than $\pm 2^o$, corresponding up to about 4 mol. per cent of Mg_2SiO_4. Measurements of $2V_Z$ of the clino-pyroxenes were corrected for refraction errors from the chart of Emmons (1943), using approximate refractive index values, and are probably accurate to within $\pm 2^o$. Longitudinal extinction angles (Z:c) for the clino-pyroxenes were measured on the universal stage on twinned crystals where possible, and supplemented by measurements in slides from sections showing maximum birefringence and flash optical interference figures.

Compositions of the clino-pyroxenes are only broadly determinable from this optical data, particularly the titan-augites, which show wide variations in optical values and compositions (Deer, Howie and Zussman, 1963). However, the compositions of some of the clino-pyroxenes in the Corra Linn basalt were determined by micro-probe analysis, through the courtesy of D.H. Green and N. Gray, Australian National University (Table 2).

Plagioclase compositions were determined from maximum symmetrical extinction angles on albite twins in sections normal to 010. Opaque iron oxides were identified from polished thin sections by reflected light microscope. Potash bearing feldspars and analcimes were confirmed in a number of cases by etching with **H.F.** and staining with sodium cobaltinitrite. Amygdale minerals were determined both from optical properties in slides and by X-ray powder photography in a number of cases.

Olivines.

The order of crystallisation observed in the Tamar lavas clearly indicates that much of the olivine was present at an early stage and had suffered partial solution prior to both extrusion and final consolidation, giving corroded phenocrysts. Crystallisation of olivine, however, was progressive and separation continued on extrusion, as in almost all cases the phenocryst fraction grades down into groundmass grains. The olivine shows differing degrees of alteration to serpentine, "bowlingite", carbonates, chlorite and iron ore, and this is marked in the late stage crystallisations of the coarse lavas.

The olivine ranges from forsterite to hyalosiderite in composition ($2V_z$ 86-105^o,$\simeq$ Fo 94-55), with the majority of the crystals showing $2V_z$ between 88-95^o ($\simeq$ Fo 91-76). Some of the olivine is zoned, commonly showing more forsteritic cores, and the most fayalitic olivine occurs in the late-stage pegmatites in the coarse lavas ($2V_z$ 95-105,$\simeq$ Fo 76-55). In some of the rocks the phenocrystic olivine shows strain polarisation and translation lamallae, and clearly includes xenocrysts derived from peridotitic xenoliths, described later.

Feldspar.

The initial plagioclase crystallised in the Tamar basalts is invariably basic labradorite, with a composition of about Ab36-40, which on continued crystallisation developed more sodic outer zones reaching compositions of up to about Ab60. Twinning on the Albite, Carlsbad and Pericline ~~lavas~~ laws is common. Under conditions of slow cooling that prevailed in the thicker lavas, the plagioclase grew to considerable size, with crystals reaching over a centimetre in length in the coarsest rocks. Some late-stage analcimisation of the plagioclase occurs in the coarse analcime bearing basalts.

Late-stage alkaline feldspars, with low refractive indices, and commonly negative optical sign and undulose extinction, are developed interstitially in many of the basalts. Their compositions have not been precisely determined, but they include alkali feldspars and probably alkaline plagioclase, some perhaps comparable with the potash-oligoclase, suggested for similar intersertal feldspar in the Auckland and Hawaiian basalts (Searle, 1961). Alkali feldspar is a common component in the microlitic mesostasis found in some of the basalts, and also forms overgrowths on plagioclase in the pegmatitic phases of the coarse basalts.

Iron Ore.

This is commonly ilmenite or titano-magnetite, generally altered to leucoxene. Its separation covers a wide range during the crystallisation of the lavas. In some cases separation commenced at a very early stage to form the small inclusions within olivine phenocrysts. Much of the iron ore is euhedral to subhedral and crystallised on extrusion, but many of the rocks also show iron ore moulding groundmass minerals and forming skeletal or long lath-like crystals typical of late-stage crystallisation. Finally, in many cases the mesostases in the rocks are charged with crystallites and globules representing the incipient crystallisation of iron ore just prior to solidification.

Clino-pyroxenes.

The clino-pyroxenes in the Tamar lavas include augite, titan-augite and aegirine-augite, and show a wide range in optical properties and textures, reflecting considerable variation in composition and a complex pattern of crystallisation. This is discussed here at some length, but some of the conclusions inferred from the optical data require confirmation by further chemical analyses. Three distinct stages of clino-pyroxene crystallisation can be recognised in the Tamar lavas.

The first stage involved the crystallisation of aluminous augite ($2V_z$ 50-56°, Z:c 47-49°) relatively high in sodium and low in calcium content (analyses 1 and 2, Table 2), and is only represented as remnant xenocryst cores in the Corra Linn basalt. The chemistry of this augite is consistent with its crystallisation at high pressure, suggesting that the crystals probably separated in the magma at depth and possibly represent the liquidus phase (D.H. Green, pers. comm.). The crystals were presumably carried to the surface out of equilibrium by a rapid ascent of the magma.

The second stage of clino-pyroxene crystallisation is represented by the crystallisation of augite in reaction rims around the augite xenocrysts. This augite ($2V_z$ 50-62°, Z:c 44-52°; analysis 3, Table 2) is lower in alumina and soda and higher in lime compared with the augite cores, and presumably crystallised at lower pressures following reaction and resorption of the cores as the magma rose to higher levels.

The third stage of clino-pyroxene crystallisation is represented by the normal separation of clino-pyroxene about the time of extrusion, and in the Corra Linn basalt this pyroxene mantles the augite of the xenocrysts and their reaction rims. This stage commenced after considerable separation of olivine and usually more or less simultaneously with the crystallisation of plagioclase. In part of the tholeiitic olivine-basalt from 7EX Hill crystallisation of the clino-pyroxene and feldspar had barely commenced upon chilling into a glassy base containing crystallites and skeletal crystals of these minerals. In the olivine-basalts of the lower Tamar area the crystallisation of the two minerals commenced on extrusion and olivine is the only phenocryst fraction. The porphyritic texture in the basalt at East Arm, correlated with the upper olivine-basalt in the lower Tamar, is interpreted as resulting from prolonged growth of feldspar, and to a lesser extent the pyroxene, below more slowly cooling lava within the neighbourhood of a feeder vent. On the other hand, in the later, wide-spread, undersaturated olivine-basalts and analcime bearing coarse olivine-basalts the clino-pyroxene appears to have begun crystallisation by the time of extrusion, giving sporadic, glomeroporphyritic, partly corrosion-riddled phenocrysts, and small, euhedral micro-phenocrysts in the finer grained and chilled contact rocks. Once started, the separation and growth of clino-pyroxene in the Tamar lavas appears to have progressed until solidification was completed.

In the finer grained lavas the bulk of the crystallised pyroxene is intergranular, with only limited or incipient intergrowth with the feldspar. In the coarser grained lavas, however, there is also late-stage crystallisation of the clino-pyroxene in large subophitic to ophitic plates, apparently formed from prolonged growth in slowly cooling parts of thick flows, aided by the presence of volatile-rich residual fluids. In extreme cases in the pegmatitic phases of these coarse lavas, the pyroxenes develop complex graphic and dendritic intergrowths. In the nepheline bearing lavas the feldspathoid crystallised at a fairly late stage compared to much of the pyroxene, so that these rocks show groundmass textures ranging from ophitic to poikilitic and grading to hyaloophitic to hyalopilitic.

The normal clino-pyroxenes in the Tamar lavas are augites that are commonly zoned, generally gradationally, and normal, reverse, oscillatory, hour-glass, complex and colour zoning may be developed. Simple and lamellar twinning on 100 and 010 is often present. These augites show wide variations in optic axial and longitudinal extinction angle values; these are tabulated in detail in the petrographic descriptions, but are summarised and discussed here in relation to the probable compositional trends of the augites.

The colourless to pale brown augite in some of the olivine-basalts, and the early colourless augite in the partly corrosion riddled phenocrysts and the inner cores of the titan-augites in the more undersaturated and alkaline lavas, generally shows normal zoning in the range of $2V_z$ 53-66° and Z:c 46-54°. This ~~augite~~ suggests a diopsidic or salitic augite, probably grading to a composition similar to that in the augite overgrowths around the xenocrysts in the Corra Linn basalt (analysis 4, Table 2).

The incorporation of titanium into the augites to give violet coloration and pleochroism (X pale yellow to yellowish brown, Y pale to deep violet, Z pale to deep violet or purple) no doubt causes complex compositional changes through accompanying balancing substitutions and gives the wide range observed in optical properties. In many of the Tamar rocks the zoned titan-augites, particularly those of late-stage crystallisation show a general increase in both optic axial and longitudinal extinction angles from core to rim, within the range $2V_z$ 41-77^o (core) to 58-84^o (rim) and Z:c 33-62^o (core) to 38-66^o (rim). The higher values commonly, but not always, correlate with a strengthening of colour and pleochroism in the outer zones. These values range notably higher than the normal limits of $2V_z$ and Z:c for augites (including titan-augites), except for sodian augites (Deer, Zowie and Hussman, 1963). This, considered in conjunction with marginal gradation and alteration of a number of these optically extreme titan-augites into greenish aegirine-augite (Z:a 46-18^o; inner zone to rim), suggests that the high values may be due to the incorporation of significant amounts of sodium, possibly as a solid solution of titan-augite and soda-augite. Such intermediate clino-pyroxenes have been described by Yagi (1953) from alkaline rocks in the Sakhalin area, and it is interesting to note that the host dolerites show a similar chemistry to the coarse olivine-basalts of the Tamar suite.

In contrast, some of the titan-augites of the Tamar lavas show generally lower optical values, with a decrease of optic axial angle and an increase of longitudinal extinction angle from core to rim, within the range $2V_z$ 52-66^o (core) to 41-53^o (rim) and Z:c 34-49^o (core) to 38-54^o(rim). This tends to occur in the finer grained lavas and is more typical of the normal trend in zoned augite (Wilkinson, 1956b; Deer, Howie and Zussman, 1963); sodium presumably has not entered into these augites to any great degree.

An interesting comparison can be made with the trends in optical behaviour of titan-augites of the Tamar lavas and the similar Auckland basalts of New Zealand (Searle, 1961). The typical titan-augite of the Auckland basalts generally forms small crystals in fine grained lavas, with $2V_z$ 56-72^o and Z:c 41-52^o, and almost universally the 2V values decrease and Z:c values increase from the inner to outer zones. On the other hand, in rare coarse phases with strongly coloured, zoned titan-augite $2V_z$ and Z:c both increase from paler inner zones to darker outer zones, e.g. in the Domain basanite with $2V_z$ 42-48^o (inner zone) to 63-64^o (outer zone) and Z:c 47-52^o (inner zone) to 54-61^o (outer zone). Thus, there is a parallelism in the titan-augite trends of the two suites, but in the Tamar rocks the trend shown by the late-stage titan-augite is much more prominent, probably largely as a result of slower cooling and crystallisation in thicker lavas.

A further trend is also noted in the Tamar rocks in cases where titanium depletion has reversed the typical late-stage trend. These titan-augites show paler coloured outer rims that show a decrease in both $2V_z$ and Z:c within the range $2V_z$ 59-66° (inner zone) to 41-53° (outer zone) and Z:c 47-49° (inner zone) to 41-42° (outer zone). These values suggest that with the titanium depletion sodium may also be lost from the augite structure and accomodated in the residual mesostasis of the rock.

Finally, clino-pyroxenes have crystallised in a number of the Tamar lavas through reaction with incorporated sedimentary xenoliths. This clino-pyroxene occurs within the fused xenoliths and/or around them in reaction rims; sporadic clino-pyroxene aggregates in the rocks probably represent the extreme case of this replacement. The clino-pyroxene is colourless to pale brown or violet and is commonly prismatic. Measurements on zoned crystals gave $2V_z$ 67° (core) to 58° (rim) and Z:c 43° (core) to 53°(rim). Similar clino-pyroxene replacements are described in xenoliths in the Auckland basalts by Searle (1962) and his detailed remarks on their formation are probably equally applicable to those of the Tamar rocks.

<u>Feldspathoids and Accessory Minerals.</u>

Nepheline is represented as a major constituent in the olivine- nephelinites and the nepheline-basanite of the Tamar suite. It generally forms poikilitic areas in a glassy groundmass, but becomes more coarsely crystalline in some phases and forms large zoned crystals up to over 5 mm. in length in the nephelinite pegmatite at Spring Bay. No detailed analytical or optical work was done on the nepheline. Analcime occurs in the coarse olivine-basalts as anhedral interstitial fillings, and staining tests indicate that some of the analcime is potash-bearing. Apatite is invariably present, ranging from small needles in the mesostasis to coarse elongated prisms. Small prisms and needles of aegirine-augite and small flakes of biotite are common minor accessories in the rocks containing an alkaline mesostasis.

Mesostases.

The majority of the Tamar lavas contain glassy or microlitic mesostases that in some cases form a considerable proportion of the rock. Glassy mesostases are developed in the finer grained rocks and the microlitic mesostases are best developed in the coarse olivine-basalts. The tholeiitic olivine-basalt from 7EX Hill contains an abundant black, opaque, glassy mesostasis typical of such basalts in Tasmania, but in the alkaline lavas the glassy mesostasis is commonly a clear to cloudy glass containing crystallites, and in some cases passes into a brown glass darkened with incipient crystallisation of iron ore. Four gradational varieties of microlitic mesostases can be recognised in the coarse basalts. Mesostasis type 1 consists largely of intersertal alkaline feldspars associated with small prisms and crystallites of titan-augite, commonly altered to aegirine-augite, grains and globules of iron ore, some zeolite and some clear glass. Mesostasis type 2 is similar, but zeolite predominates and consists mainly of analcime and fibrous radiating species. Mesostasis type 3 consists of numerous small laths and curved to spherulitic microlites of alkali feldspar, associated with prisms of apatite, small grains and crystallites of iron ore and flakes of biotite, in a zeolitic analcime-rich base containing indeterminate chloritic or serpentinitic material. Mesostasis type 4 resembles type 3, but lacks the indeterminate greenish material. Mesostasis types 3 and 4 are typically developed in the pegmatitic phases, in some cases forming over half the rock. A further kind of mesostasis is developed in the lower olivine-basalt in the lower Tamar and consists largely of carbonates (including siderite) and chloritic, nontronitic or serpentinitic clays, and more rarely a zeolite resembling chabazite.

Amygdale, Joint and Vein Minerals.

Opal, chalcedony, carbonates and clays are common secondary minerals in the tholeiitic olivine-basalt of 7EX Hill and the lower olivine-basalt in the lower Tamar. Zeolites are common in amygdales and veinlets in the alkaline lavas and include natrolite, gonnardite(?), stilbite, thompsonite, phillipsite and chabazite. Other accompanying minerals that may be present are apophyllite, gyrolite, diaspore or gibbsite (?), carbonates and clays. Pyrite coats joint planes in the lower olivine-basalt in the lower Tamar.

Xenoliths.

A number of the Tamar lavas carry accidental xenoliths of the country rocks. Small fused and partially replaced pieces of Tertiary sediments are relatively common. Xenoliths of Jurassic dolerite, in which the mesostasis has been partly fused and recrystallised, were noted in the Corra Linn basalt and in the olivine-nephelinite east of St. Leonards.

Small peridotite nodules occur in the olivine-nephelinites at Spring Bay and east of St. Leonards, in the nepheline-basanite at Deviot, in the coarse olivine-basalt on the East Arm foreshore, and in the olivine-pyroxene-basalt at Corra Linn. The nodules are composed mostly of olivine, associated with some clino-pyroxene. The olivine ($2V_z$ 86-95, $\simeq$ Fo 94-76) commonly shows strain polarisation and translation lamellae and clearly forms part of the phenocrystic fraction of the host lava through disaggregation of the nodules. The clino-pyroxene ($2V_z$ 53-67°, Z:c 46-50°) is a colourless aluminous augite that approaches an endiopsidic composition judging from the analysis from a nodule collected from basalt at Blessington (analysis 6, Table 2). The nodules also contain minor colourless enstatite, rare labradorite ($\approx$ Ab37) and green, brown or grey ferroan and chrome (?) spinels (analysis 5, Table 2).

Similar peridotite nodules are known elsewhere in Tasmania (Sutherland, 1968b), on the Australian mainland (Joplin, 1964) and in New Zealand (Searle, 1961; Black and Brothers, 1965); their distribution is world wide in basaltic rocks (Green and Ringwood, 1967). Their origin has been disputed: some authors consider that they represent disrupted segregations and accumations of crystallites within magma chambers, (Searle, 1960, 1961; Brothers, 1960; Wager, 1962; etc.), but others consider that their origin is deep seated and probably derived from the mantle (Turner and Verhoogen, 1960; Wilshire and Binns, 1961; etc). This question has been reviewed by Black and Brothers (1965) following detailed textural studies on nodules from Tokatoka, New Zealand, and more recently by Green and Ringwood (1967) who consider that they represent remnants derived from the mantle.

DIFFERENTIATION IN THE TAMAR LAVAS.

Differentiation trends.

These can be distinguished in the Tamar suite, both between separate lavas and within individual lavas, by reference to the variation diagram for plots of their solidification index (Kuno, 1959) against SiO_2, Na_2O and K_2O (Figure 16).

The lower olivine-basalt in the Lower Tamar (analysis 1, Table 1) plots as the least differentiated of the Tamar lavas on this diagram, suggesting that it may represent a composition close to its parent magma. The Corra Linn basalt with its complement of augite xenocrysts from depth (analysis 9, Table 1) also plots as a little differentiated lava. Another plot with a solidification index over 40 is the picritic phase of the coarse olivine-basalt of the middle Tamar, but in this case differentiation within the basalt itself has spread the apparent values (analyses 4-6 and 13, Table 1), and the average of these suggests a slightly differentiated lava.

Most of the Tamar lavas, if internal differentiation is discounted, fall in the field of slightly differentiated rocks with solidification indices between 30 and 40. The nepheline-basanite (analysis 14) appears to be a slightly differentiated variant of the undersaturated titan-augite olivine-basalts of the Tamar (analyses 7, 10 and 11, Table 1). The olivine-nephelinite (analysis 16, Table 1) with its solidification index of over 35 appears to be an alkaline variant, only relatively little modified by differentiation. The limburgite (analysis 17, Table 1) with its solidification index of greater than the majority of the Tamar lavas suggests an early differentiate from its parent magma.

Variations in modal mineralogy, texture, chemical composition and solidification index in the coarse basalts of the Tamar suggest differentiation within the thicker parts of these flows (Plates 28, 29 and 31; analyses 4,5,6, 8 and 13, Table 1; Figure 16). This is most marked in the middle Tamar area and basalts were sampled here from four levels at East Arm for chemical analysis: from picritic basalt in the lower levels of a valley fill at river level (analysis 5); from 150 feet above river level in the upper part of the valley fill from olivine-poor mesostasis-rich basalt (analysis 6); from basalt capping the hill at about 250 feet adjacent to the valley fill (analysis 4), presumably representing less differentiated basalt; and from pegmatite at ~~35~~ 350 feet (analysis 13), presumably representing a late stage differentiate of the basalt capping. The analyses reflect the general modal compositions of the rocks; the picritic phase shows relative enrichment in magnesia and ferrous iron and impoverishment in silica, alumina and ferric iron compared with the basalt of the flow capping, and the mesostasis-rich and pegmatitic phases show relative enrichment in silica, alumina and ferric iron, and impoverishment in magnesia and ferrous iron. This differentiation trend is seen in the chemical variation diagrams (Figures 14, 15 and 16), and the solidification indices of the rocks spread from over 45 for the picritic phase to less than 25 for the pegmatitic phase, thus passing into the field of moderately strongly differentiated rocks (Figure 16). Coarse olivine-basalt from the upper part of the flow, south of Atkinsons Creek in the upper Tamar, also shows relatively low magnesia and high alumina and silica, suggesting some differentiation (analysis 8).

Differentiation and Behaviour of Titanium in the Clino-pyroxenes.

Differentiation within the Tamar lavas has produced two trends of crystallisation of the pyroxenes in regard to the behaviour of titanium, often discriminated in alkali rocks (Yagi and Onamu, 1967); i.e. an initial trend of titanium enrichment in the earlier stages of fractionation, and a late reverse trend of titanium depletion in the middle and later stages of differentiation. Evidence of titanium enrichment in pyroxenes during early stages of fractionation is found in the following cases;

1) in the upper basalt in the lower Tamar and in the limburgite in the south Tamar areas, in which later stage pyroxenes crystallising in the mesostasis take on deepening violet coloration compared with ~~to~~ the near colourless earlier groundmass pyroxene;

2) in the undersaturated olivine-basalts and coarse olivine-basalts, in which early pyroxenes with corrosion riddling are essentially colourless compared with violet coloured pyroxenes in the bulk of the rock.

3) in the undersaturated olivine-basalts and coarse basalts, in which there is deepening of colours

towards the outer zones of the pyroxene crystals, becoming particularly marked in the late-stage ophitic plates or in the presence of an abundant microlitic mesostasis.

4) in the olivine-pyroxene-basalt from Corra Linn, in which the pyroxene overgrowths around the augite xenocrysts show a progressive change outwards from colourless to violet coloured augite.

Evidence of titanium depletion in pyroxenes during the later stages of fractionation in the Tamar rocks is found;

1) in the late-stage pegmatitic veins and segregations in the coarse olivine-basalts and olivine-nephelinite, in which some of the titan-augites show paler coloured outer zones;

2) in the coarse basalts in which titan-augite in contact with, or within the late-stage mesostasis is altered to greenish aegirine-augite, as these soda pyroxenes are generally poor in titanium relative to titan-augite (see Yagi and Onamu, 1967; Deer, Howie and Zussman, 1963; Tables 12 and 20).

Differentiation Within Lavas

The available evidence suggests that the coarse basalts of the Tamar probably represent flows several hundred feet in thickness. Such thicknesses of lava would cool relatively slowly and seem adequate for differentiation to take place, based on known thicknesses of differentiated sills (200-700 feet thick) of similar rock composition elsewhere in Australia (Joplin, 1964). Differentiated sills such as the Prospect and Black Jack teschenite bodies in New South Wales (Wilshire, 1967; Wilkinson, 1958; Joplin, 1964) and the differentiated crinanite in necks at Circular Head and Table Cape (Edwards, 1941; Gill and Banks, 1956; Gee, 1966), resemble the coarse basalts of the Tamar in many petrological features, although they show differences in details of differentiation.

The Circular Head and Prospect rocks crystallised from a parent magma of similar composition to that of the coarse basalt of the Tamar, but the Black Jack body ~~appears to~~ crystallised from a slightly more alkaline magma, and all the differentiates are nepheline-normative, unlike some of the Prospect and Tamar rocks. The differentiation process in the sills and necks appears ~~to have been~~ more pronounced than in the Tamar lavas, and the highly alkaline differentiates of these bodies, such as analcime-syenite and tephrite were not noted in the Tamar rocks.

Differences in compositional trends of the mineralogical phases separating during crystallisation can also be noted, as on comparing the olivines and clino-pyroxenes of the Black Jack and Tamar rocks. The late olivine in the Black Jack sill (Wilkinson 1956a) shows greater iron enrichment than that in the late pegmatites of the coarse basalts of the Tamar, and this is presumed to reflect more lengthy cooling in a sill compared with a lava of comparable thickness. In the clino-pyroxenes of the Black Jack sill, Wilkinson (1957) notes an increase in reverse zoning with $2V_{margin} > 2V_{core}$ as in the later titan-augite in the Tamar rocks. However, here, the increase appears to be due to the introduction of magnesium, and the titan-augites show decreased titanium contents, no significant increase in sodium content, and in contrast lack the extreme high values of $2V_z$ and Z:c shown by the Tamar titan-augites.

Comparison of the differentiation trends of the Black Jack, Prospect and Circular Head bodies, plotted in the variation diagrams in Figures 14, 15 and 16, with that of the coarse basalt of the middle Tamar (analyses 4-6 and 13) reveals some interesting differences. The Tamar trend differs markedly from that of the Circular Head crinanite trend, and although it again shows some differences, lies more closely to the femic extension of the Black Jack and Prospect trends. This suggests that the differentiation processes operating in thick flows of alkaline magma approach those shown by sills rather than ~~in~~ necks.

Coarse olivine-basalt closely matching the Tamar basalts is also found in Tasmania at Mt. Cameron West, apparently forming a single flow over 400 feet thick (Gill and Banks, 1956; Sutherland and Corbett, 1967). However, the rock at Mt. Cameron West is not much differentiated and no marked pegmatitic or picritic phases were noted. This may have resulted from the lava here filling a narrower valley than in the Tamar and probably cooling more quickly relative to the process of differentiation. Thus, not only a sufficient depth, but also a sufficient width of lava, appears to be required for noticeable differentiation to take place in such flows.

The pegmatites of the Tamar basalts represent the extreme phase of the differentiation, with enrichment of silica, titania, soda and potash at the expense of magnesia and lime. They occur mostly in the lower levels of the flows, showing that the parent residual fluids accumulated deep within the flows without wholesale migration into the upper levels; rocks with coarser ophitic textures and deeper coloured titan-augite are also found in the lower half of the Mt. Cameron West flow. This behaviour contrasts with that normally found in differentiated sills, where the coarsest rocks and pegmatites tend to form in the upper levels e.g. Black Jack, Prospect and Tasmanian Jurassic dolerite sills (Wilkinson, 1958; Wilshire, 1967; Joplin, 1964). This, no doubt, results from relatively more rapid chilling and crystallisation in the upper levels of flows, arising from a more unequal temperature gradient from top to bottom, compared with sills.

Fractionation trends ~~at~~ of basalt magmas in lava flows are discussed by Kuno (1965) but his examples are drawn from tholeiites, high-alumina basalts and basaltic andesites rather than alkali basalts. Kuno considers that different trends in total iron and silica contents during differentiation arise largely from differences in oxygen partial pressure, probably due to differences in the initial water contents of the magma. The coarse basalt in the middle Tamar shows a typical alkali basalt trend of increasing silica and nearly constant total iron, which according to Kuno would indicate a high oxygen pressure and hence probably a high initial water content. The presence of abundant pegmatites and mesostasis-rich phases in the basalt, carrying hydrous minerals such as analcime, other zeolites, biotite and chlorite fully supports this.

PETROCHEMICAL AFFINITIES OF THE TAMAR LAVAS.

The Tertiary volcanic rocks of the Tamar Trough range from undersaturated lavas such as olivine-nephelinite, nepheline-basanite and limburgite through undersaturated and near-saturated olivine-basalts to saturated olivine-basalt. The bulk of the lavas are undersaturated to near-saturated olivine-basalts, with the other rocks only forming small restricted flows. In general, the Tamar suite can be regarded as predominantly an alkaline association, with minor tholeiitic lava, as discussed later. In this study the petrochemical affinities of the Tamar lavas are examined in relation to similar Cainozoic volcanic associations in the Australian region and then compared with a few of the well known petrographic suites elsewhere in the world.

Australasian Affinities.

Alkaline volcanic suites similar to the Tamar lavas are found elsewhere in Tasmania (Edwards, 1950; Spry, 1962; Sutherland, 1968a, 1968b, and herein); in eastern Australia, best typified by the Older Volcanic series of Victoria (Edwards, 1939, 1950); and in New Zealand, best typified by the Auckland Basalts (Searle, 1961). The available petrochemical data on the Tasmanian Cainozoic volcanic province (including that of the Tamar suite) is discussed by Sutherland (1968b) and a further analysis is not attempted here. Detailed petrochemical data are scanty for the Older Volcanic series of Victoria, but the average calculated basalt (Edwards, 1939) compares closely with that of the Tamar suite (analysis 12, Table 1). Detailed petrochemical data has been presented for the Auckland Basalts (Searle, 1961), enabling a close comparison with the Tamar suite.

The Tamar alkali basalts (analyses 1 to 11, Table 1) chemically resemble the Auckland basalts in degree of silica undersaturation, in relatively high alkali contents, and in alumina contents mostly in excess of magnesia and present in approximately sub-equal amounts with lime and ferrous oxide. The average calculated composition of the Tamar basalts (analysis 12, Table 1) is very close to that of the average Auckland basalt and indicates a similar parent magma, chemically intermediate between the "normal alkaline basalt" and the "olivine-rich alkaline basalt" of Nockolds (1954). The Tamar basalts, however, tend to be somewhat richer in iron oxide at the expense of magnesia, compared with the Auckland rocks, and this is probably reflected in the relatively more common occurrence of picrite basalts amongst the Auckland lavas.

Norms calculated for the Tamar basalts (Table 1) resemble those of the Auckland basalts in that some of the rocks show noticeable amounts of normative nepheline, which finds little or no modal expression. In the Auckland rocks the excess soda is apparently incorporated into the residual groundmass feldspar and mesostasis. The Tamar basalts show a similar behaviour, although in the coarser basalts the excess soda appears as analcime. Further, the presence of titaniferous augites in the rocks will increase the available silica by substitution, (probably Ti for Mg, accompanied by Al for Si; see Yagi and Onamu, 1967), and in reality diminish the apparent values of normative nepheline. Some of the Tamar basalts also contain some aegirine-augite and sodian titan-augites (judging from their optical properties as previously discussed), and this would also use some of the available soda.

Although some of the Tamar basalts approach basanites in regard to their chemistry and calculated normative nepheline, mineralogically they are olivine-basalts grading to analcime bearing olivine-basalts. Rocks termed basanites in the Tamar suite and elsewhere in Tasmania, and on mainland Australia, generally show slightly greater alkali contents (analysis 14, Table 1; Spry, 1962, Analyses 108-109; Joplin, 1963, Tables N and O), as does the average teschenite (and corresponding lavas) of Nockolds (1954). Of particular interest in this respect is the nepheline-basanite at Deviot, with about 8% modal nepheline, which grades into an analcime bearing coarse olivine-basalt, with only a slight decrease in alkalies and a slight increase in silica (analysis 15, Table 1). This indicates strong sensitivity between the chemistry and mineralogy in such rocks.

The general lack of modal nepheline in basalts in the presence of high normative nepheline is typical of the rocks belonging to the alkali-rich, sub-aluminous associations of the Pacific Basin (Barth, 1931). The alkali and calcic contents of the Tamar rocks, with the field of the Auckland Basalts for comparison, are plotted on a ternary diagram (Figure 13) similar to that used by Searle (1960), after Green and Poldervaart (1954). The diagram plots the relative number of ions of K-Na-Ca (data from Table 1) and illustrates the close affinities of the Tamar and Auckland suites, and the distribution relative to the trend lines recognised by Green and Poldervaart. The Tamar suite, as does the Auckland suite, lies along trend B, and thus, although chemically comparable with the lavas from the sub-aluminous alkaline associations of the Pacific Basin, is possibly derived by fractionation along a trend more characteristic of a continental environment (Searle, 1960).

Relationships to Some Overseas Petrographic Provinces.

The petrochemistry of the Tamar suite (analyses 1 - 18, Table 1) is plotted on a number of variation diagrams (Figures 14, 15, and 16) and compared with trend lines of the well known Skaergaard liquid series (Wager, 1960), the Kilauean tholeiitic rocks (Tilley, 1960; Muir and Tilley, 1963) and the Hawaiian alkali basalts (Mc Donald, 1949).

In the diagram for alumina against total alkalies (Figure 14a), with basalt field boundaries from Kuno (1960) for SiO_2 45.00-47.50, the Tamar suite plots from the tholeiitic field into the alkali basalt field, with no plots in the high-alumina basalt field. The tholeiitic olivine-basalt from 7EX Hill (analysis 18) occupies an ambiguous position on the boundary between the two fields in this diagram, but would fall in the tholeiite field using the appropriate SiO_2 50.01-52.50 boundary of Kuno. In the FMA diagram (Figure 15) it falls between the Kilauean tholeiite and Hawaiian alkali basalt trends, near the Skaergaard trend. However, in the diagram for silica against total alkalies (Figure 14b) it clearly falls within the tholeiite field of McDonald and Katsura (1964), and in the diagrams for SiO_2 against FeO+

$Fe_2O_3/MgO+FeO+Fe_2O_3$ (Figure 14d), for MgO against Al_2O_3/SiO_2 (Figure 14e) after Murata (1960), and for Kuno's (1959) solidification index against SiO_2, Na_2O and K_2O (Figure 16) it is much more closely associated with the Kilauean tholeiitic trend, rather than the Hawaiian alkali basalt or Skaergaard trends.

The limburgite from "Duneiden Farm" (analysis 17) plots with the alkali basalts in a number of the variation diagrams, but in the FMA diagram (Figure 15) it plots on the Kilauean tholeiitic trend. In the diagram for alumina against total alkalies (Figure 14a) it again plots in the tholeiite field, although allowance for its more undersaturated composition in respect to the SiO_2 45.00-47.50 boundary of Kuno (1960) must be made. This suggests that the limburgite may be derived from a tholeiitic olivine-basalt parent, a possibility strengthened by its close field association with the 7EX Hill tholeiitic olivine-basalt.

The alkali olivine-basalts of the Tamar, as plotting in the diagram for silica against total alkalies (Figure 14b), form a suite of mildly alkaline basalts overlapping into the field of strongly alkaline basalts, relative to the boundary after Saggerson and Williams (1964). In the variation diagrams they plot nearest to the Hawaiian alkali basalt trend, with two main exceptions. In the diagram for alumina against total alkalies (Figure 14a) the olivine-pyroxene-basalt from Corra Linn (analysis 9) plots in the tholeiite field, but this anomaly is due partly to the presence of the numerous xenocrysts of aluminous augite in the rock, reducing the relative alumina and alkali content, and partly to its more undersaturated composition in respect to the SiO_2 45.00-47.50 boundary of Kuno (1960). Again, the upper olivine-basalt from the lower Tamar area (analysis 2), although plotting as an alkali basalt in Figures 14b, 14d and 16, plots on the Kilauean tholeiite trends in Figures 14c and 15, and this is considered to reflect the abnormally high iron content of this rock for an alkali basalt.

The alkaline differentiates represented by the more differentiated phases and the pegmatite of the coarse olivine-basalts (analyses 4,6,8 and 13), and the nepheline-basanite from Deviot (analyses 14 and 15), tend to plot as an extension of the olivine-basalts along the trend of the Hawaiian alkali basalts. Overall, the variation diagrams indicate that the Tamar alkali basalt trend approaches that of the Hawaiian alkali basalts, but shows some distinct differences, with the Tamar rocks tending to be relatively slightly more enriched in alkalies and impoverished in magnesia in respect to silica (Figures 14b, 14d). In this connection it is interesting to note that in the FMA diagram (Figure 15) the differentiated alkaline-rich, analcime bearing, coarse basalt from the middle Tamar (analyses 4,5,6 and 13) falls towards the extension of the Black Jack teschenite trend of Wilkinson (1958). The olivine-nephelinite from Spring Bay (analysis

16) plots away from the Tamar and Hawaiian alkali basalt trends in some of the variation diagrams (Figures 14b, 14d and 16). This correlates with the ideas of Bultitude and Green (1968) that such rocks differ in their genesis in some respects from that of the typical alkali basalts, a point discussed later.

THE ERUPTIVE AND MAGMATIC HISTORY OF THE TAMAR LAVAS.

The Eruptive Succession.

The Tamar extrusions have been dated to a limited extent from the field stratigraphy (Table 3), but precise datings will require detailed radiometric and palaeomagnetic studies. Thin sections of the lavas were examined for the author by Dr. I. McDougall, Australian National University, who reported that a number of the rocks appear suitable for radiometric dating.

From presently available evidence the eruptive sequence tentatively suggested for the Tamar volcanism is: initial eruptions of undersaturated to near-saturated alkali olivine-basalts in the lower and south Tamar areas during the Lower Tertiary, probably post-Middle Eocene and pre-Upper Oligocene; then a small extrusion of olivine-nephelinite in the middle Tamar area in the Lower to Middle Tertiary, probably in the Oligocene; and finally effusions of undersaturated alkaline olivine-basalts and possibly nepheline-basanite, followed by thick near-saturated coarse olivine-basalts in the middle, upper and south Tamar areas in Middle or Upper Tertiary time, probably post-Upper Oligocene and pre-Middle Pliocene. The positions in this sequence of the small extrusions of olivine-nephelinite, tholeiitic olivine-basalt and limburgite in the south Tamar are unknown.

The Cainozoic volcanic history and its relationships to the development of the Tamar Trough, as suggested by this present study, is summarised in Table 4. One feature of interest is the apparent absence of Miocene marine or littoral sediments within the Trough, an expected inlet for the major marine transgression recorded in the Miocene elsewhere in Tasmania and south-eastern Australia (Ludbrook, 1967). Although such deposits may have been removed by subsequent erosion, a possible explanation is that at the time of the higher Miocene sea the northern end of the Trough was blocked with a sufficient thickness of basalt to prevent access of the sea.

Comparison with the Victorian Volcanics.

The eruptive succession in the Tamar Trough provides further data for comparisons of the Tasmanian and Victorian Cainozoic volcanic provinces, the broader aspects of which are discussed elsewhere (Sutherland 1968a). The Tamar suite resembles the Older Volcanic series of Victoria (Palaeogene volcanism; maximal in the Eocene, Singleton, 1965), but in contrast probably includes substantial post-Upper Oligocene eruptions. However, recent work in Victoria suggests that there may be some approachment towards the Tamar and Tasmanian eruptive histories, as some basalts in the Melbourne district petrologically similar to those of the Older Volcanic series are possibly much younger in age (Thomas, et.al., 1967).

The proposed Tamar succession petrologically closely compares with a sequence established in the Older Volcanic series of Victoria at Bacchus Marsh (Jacobson and Scott, 1937). This sequence (listed from the base upwards) consists of serpentine-basalts, not unlike the lower olivine-basalt of the lower Tamar; iddingsite and porphyritic basalts, showing some similarities to the upper olivine-basalt in the lower Tamar and the porphyritic olivine-basalt in the middle Tamar, except for the "iddingsitisation" of the olivine; monchiquite dykes and olivine-nephelinites, corresponding to the olivine-nephelinite of the middle Tamar; limburgites and limburgitic basalts, some of which resemble the finer, more glassy phases of the undersaturated olivine-basalts of the upper and south Tamar and the nepheline-basanite in the middle Tamar; and the doleritic basalt, resembling the coarse olivine-basalts of the middle, upper and south Tamar areas. Flows tend to be thinner and more numerous, and olivine-nephelinites are more prominent, in the Bacchus Marsh sequence. The lava pile is faulted, tilted and more greatly stripped than the Tamar sequence, possibly suggesting an older upper age limit. These comparisons suggest a generally similar genesis and magmatic history for the two sequences, but with some differences in the eruptive pattern.

Genesis of the Tamar lavas.

The Tamar lavas form essentially an alkaline suite, apparently derived from alkali basalt parent magmas. Recent work on the genesis of basalts (Green and Ringwood, 1967) suggests that such parent magmas may be generated by a relatively restricted degree of direct partial melting of mantle pyrolite, with segregation of the alkali basalt magmas at depths of 35-70 Kms.

The initial parent magma appears to have ascended in a fairly undifferentiated state to form the lower olivine-basalt in the lower Tamar (solidification index >45, Figure 16), but then underwent some differentiation prior to further eruption to form the upper olivine-basalt (solidification indices $<35>30$).

The next phase of the volcanism appears to pass to minor extrusion of olivine-nephelinite in the middle Tamar, and possibly in the south Tamar. This rock may represent a product of more extreme differentiation of the initial alkali-basalt parent magma, but its relatively high solidification index of over 35, and its tendency to plot away from the alkali basalt trend in some of the chemical variation diagrams, infers a somewhat different origin. Recent work by Bultitude and Green (1968) suggests that such rocks may have formed during a waning in volcanism under a low degree of pyrolite melting, giving more hydrous conditions that allowed fractionation of alkali basalt magma towards such undersaturated compositions at depths of 60-100 Kms.

This was followed by the eruption of undersaturated olivine-basalts in the upper and south Tamar, presumably following renewed, more widespread generation and seggregation of alkali basalt magma at depths of 35-70 Kms. These basalts approach basanites in composition and show solidification indices between 45-35. The cognate augite xenocrysts in the Corra Linn basalt suggest that magma of this composition may have formed by fractional crystallisation of this augite from a more primative parent. Crystallisation of augite of such composition points to a parent magma significantly richer in silica, lime and magnesia and somewhat poorer in iron, alumina and alkalies, but rocks of such composition are unknown in the Tamar suite. Alternatively, however, if fractionation proceeded by crystallisation of olivine as well as augite, then this provides for relatively constant compositions in regard to lime and would give a parent magma approaching the composition of the lower olivine-basalt in the lower Tamar, but a little poorer in alkalies.

The final phase of the volcanism includes the extrusion of the coarse olivine-basalts in the middle, upper and south Tamar areas and possibly the nepheline-basanite in the middle Tamar. These lavas tend to show slight enrichment in silica, alkalies and alumina compared with the preceeding undersaturated olivine-basalts. This may reflect some differentiation within the undersaturated magma at relatively higher levels and lower pressures, as low pressure differentiation along similar trends continues within the thick lavas after extrusion.

The tholeiitic olivine-basalt, and possibly the alkali-poor limburgite, in the south Tamar area form the western outskirt of a tholeiitic olivine-basalt association to the south-east and east, overlapping into the alkaline suite of the Tamar Trough. Following the studies of Green and Ringwood (1967), the parent tholeiitic magmas for this association may have formed as the result of relatively higher degrees of partial melting of mantle pyrolite, with segregation of magma at depths of 35-70 Kms. In the broad context, the Tamar Trough falls within an alkaline volcanic association extending to the west as far as the Devonport-Deloraine area (interpreted as possibly representing an area of restricted mantle melting), but its south-eastern end passes transitionally into a dominantly tholeiitic association extending to the east as far as the Camden Plains-Avoca area (interpreted as possibly representing an area of greater mantle melting). The overall aspects of the Cainozoic Volcanism of the Tasmanian province, including that of the Tamar Trough, are reviewed elsewhere (Sutherland, 1968b).

ACKNOWLEDGEMENTS.

The author wishes to acknowledge the assistance of numerous persons who contributed to this work. In particular he wishes to thank the following for helpful discussion, information, or advice, on the geological aspects of the work: Dr. A.H. Spry, Monash University, Victoria; Professor S.W. Carey, Dr. R. Varne, Mr. M.R. Banks, Mr. D. McP. Duncan, Mr. C. Gee and Mr. D.I. Groves, Geology Department, University of Tasmania; Mr. E.D. Gill, National Museum of Victoria; Mr. K.D. Nicolls and Mr. G. Dimmock, C.S.I.R.O. Division of Soils; Mr. M.J. Longman, Dr. R.D. Gee, Mr. W.L. Matthews, and Dr. E. Williams, Mines Department of Tasmania; Dr. K.L. Burns, Geology Department, Macquarie University; Dr. D.H. Green, Dr. I. McDougall and Mr. N. Gray, Department of Geophysics and Geochemistry, Australian National University; Mr. W.K. Harris, Mines Department of South Australia; and Mr. R.C. Kershaw and Mr. J. Allchin of Launceston.
The work has greatly benefited from the help of Mr. I. Jennings, Chief Geologist, Mines Department of Tasmania and Mr. D.I. Groves, Mrs. G. Sanders, and Mr. R.J. Ford, Geology Department, University of Tasmania, who arranged some chemical analyses. Considerable help with geological reports and bore cores was extended by Mr. J.K. Edwards, Port Manager, Launceston Marine Board, and Mr. A.L. Ellis, General Manager, Comalco Aluminium (Bell Bay) Ltd. The author also wishes to thank Mr. T.D. Hughes, former

Chief Geologist, and Mr. G. Everard of the Mines Department of Tasmania, for assistance with thin sections; Mr. W. Peterson, Geology Department, University of Tasmania, for assistance with microslide photography; and the officers of the Tasmanian Department of Public Works and Lands and Surveys, for their co-operation. Most of the field work was done while the author was employed at the Queen Victoria Museum, Launceston, and much help and guidance was given by Mr. W.F. Ellis, Director of the Museum, and the staff at the Launceston City Council. The work was completed at the author's present place of employment and he wishes to thank Dr. W. Bryden, Director, and Mr. M. Bower, of the Tasmanian Museum, Hobart. Finally the author wishes to acknowledge the help and encouragement of his wife, Nancy, both during the field mapping and the writing up of this work.

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C. I.P.W. Norm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.25
Or	8.33	5.91	6.80	6.44	8.51	7.51	9.22	7.68	5.91	6.32	9.46	7.45	9.22	6.97	6.56	8.87	9.46	3.78
Ab	10.23	23.69	25.17	25.73	4.45	28.52	8.32	22.85	9.98	10.31	12.30	17.87	34.27	18.24	27.49	4.80	5.55	22.42
An	14.35	17.22	22.41	18.77	14.22	23.39	19.59	24.15	24.28	21.44	19.25	19.93	16.34	13.68	17.33	12.70	18.30	23.76
Ne	9.13	0.00	2.59	3.34	15.15	0.00	9.52	0.00	4.68	8.30	4.80	4.48	0.00	8.96	1.66	13.90	5.24	0.00
Di	19.03	16.00	17.76	20.05	25.05	17.56	19.67	16.09	21.70	22.87	17.15	19.33	17.42	24.19	16.28	21.05	26.05	13.88
(En	(6.30	(4.71	(5.30	(5.51	(7.93	(6.02	(6.92	(4.56	8.24	(8.02	(5.78	(6.29	(5.10	(7.12	(4.86	(7.06	(8.88	(4.17
(Fs	(2.89	(3.11	(3.36	(4.34	(4.22	(2.44	(2.53	(3.32	2.09	(2.96	(2.49	(3.07	(3.41	(4.69	(3.09	(3.10	(3.67	(2.60
(Wt	(9.84	(8.19	(9.09	(10.20	(12.89	(9.11	(10.23	(8.20	(11.37	(11.89	(8.88	(9.97	(8.91	(12.38	(8.34	(10.90	(13.50	(7.11
Hy	0.00	8.13	0.00	0.00	0.00	3.68	0.00	5.40	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	25.37
(Et	(0.00	(4.90	(0.00	(0.00	(0.00	(2.62	(0.00	(3.12	(0.00	(0.00	(0.00	(0.00	(0.24	(0.00	(0.00	(0.00	(0.00	(15.66
(Ft	(0.00	(3.22	(0.00	(0.00	(0.00	(1.06	(0.00	(2.27	(0.00	(0.00	(0.00	(0.00	(0.16	(0.00	(0.00	(0.00	(0.00	(9.70
Ol	29.05	15.28	16.21	14.43	22.91	6.11	19.39	13.57	20.29	17.87	21.04	19.04	9.48	17.23	20.20	21.67	20.67	0.00
(Fo	(19.30	(9.15	(9.55	(7.73	(14.44	(4.23	(13.83	(7.53	(15.87	(12.70	(14.27	(12.38	(5.46	(9.98	(11.88	(14.60	(14.20	(0.00
(Fa	(9.75	(6.67	(6.67	(6.71	(8.47	(1.89	(5.56	(6.04	(4.43	(5.17	(6.77	(6.65	(4.02	(7.25	(8.32	(7.07	(6.46	(0.00
Mt	0.45	5.37	2.07	1.46	1.35	5.23	6.24	4.06	5.95	6.38	6.82	4.12	4.12	2.22	3.12	5.66	5.80	2.07
Il	3.46	4.18	3.80	4.08	4.81	4.27	4.37	3.04	4.37	4.37	4.18	4.08	6.10	4.60	4.50	5.32	4.75	3.38
Ap	1.26	1.40	1.97	1.00	1.04	1.04	3.62	1.21	1.47	1.87	2.04	1.63	1.47	2.32	1.00	2.84	1.97	0.43
$H_2O^{\pm}$	2.78	2.01	2.09	3.92	1.73	1.93	1.15	2.17	1.78	0.96	2.80	2.11	2.09	2.53	3.33	2.89	1.52	1.84
Total	98.07*	99.73	100.87	99.22	99.22	99.24	101.09	100.22	100.41	100.69	99.84	100.04	100.90	100.94	101.47	99.70	99.31	99.18

Table 1. Chemical Analyses and Molecular Norms . Tamar Tertiary Lavas.

Analysis.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SiO_2	43.78*	46.3	47.93	47.21	43.12	48.40	42.3	47.5	43.0	43.2	42.2	45.18	49.53	45.95	47.48	40.0	42.0	51.5
Al_2O_3	12.05	12.0	15.28	14.26	13.07	15.49	13.9	14.7	13 .6	14.0	12.9	13.75	14.34	13.05	13.49	12.2	11.4	13.7
Fe_2O_3	0.31	3.7	1.43	1.01	0.93	3.61	4.3	2.8	4.1	4.4	4.7	2.84	2.84	1.53	2.15	3.9	4.0	1.4
FeO	9.98	11.6	8.78	9.33	10.83	6.67	9.2	9.8	8. 0	9.2	10.0	9.40	8.76	10.29	10.45	10.7	10.4	8.7
MnO	0.24	0.20	0.19	0.15	0.13	0.21	0.1	0.20	0.17	0.1	0.22	0.17	0.18	0.24	0.19	0.24	0.2	0.1
TiO_2	1.82	2.2	2.00	2.15	2.53	2.25	2.3	1.6	2.3	2.3	2.2	2.15	3.21	2.42	2.37	2.8	2.5	1.7
P_2O_5	0.53	0.59	0.83	0.42	0.44	0.44	1.53	0.51	0.62	0.79	0.86	0.69	0.62	0.98	0.42	1.2	0.83	0.1
CaO	8.34	8.2	10.00	9.26	9.67	9.69	10.9	9.5	11.2	11.1	9.3	9.74	8.41	10.02	8.07	9.4	11.3	8.4
MgO	13.59	9.1	7.60	6.64	11.46	5.89	10.7	7.4	12.4	10.5	10.5	9.62	5.27	8.58	8.76	11.2	11.7	7.9
Na_2O	3.20	2.8	3.54	3.77	3.83	3.37	3.06	2.7	2.2	3.03	2.5	3.09	4.05	4.11	3.61	3.6	1.8	2.6
K_2O	1.41	1.0	1.15	1.09	1.44	1.27	1.56	1.3	1.0	1.07	1.6	1.26	1.56	1.18	1.11	1.5	1.6	0.6
Ignition Loss	2.13	1.3	1.45	3.52	1.57	1.59	1.05	1.5	0.94	0.80	1.7	1.59	1.45	2.05	2.80	2.0	1.12	1.6
H_2O^-	0.65	0.71	0.64	0.40	0 .16	0.34	0.10	0.67	0.84	0.16	1.1	0.52	0.64	0.48	0.57	0.89	0.40	0.1
Total.	98.03*	99.70	100.82	99.21	99.42	99.22	100.90	100.18	100.37	100.65	99.78	100.00	100.86	100.88	101.47	99.63	99.25	99.1

CATION/UNIT CELL. OXYGEN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Si	26.94	28.61	29.04	28.66	26.94	29.14	26.36	28.98	26.57	26.88	26.36	27.79	30.01	28.34	29.02	25.28	26.42	31.00
Ti	0.84	1.02	0.91	0.98	1.19	1.02	1.08	0.73	1.07	1.08	1.03	1.00	1.46	1.12	1.09	1.33	1.18	0.81
Al	8.74	8.74	10.91	10.20	9.62	10.99	10.21	10.57	9.91	10.27	9.50	9.97	10.24	9.49	9.72	9.09	8.45	9.76
Fe^{+++}	0.14	1.72	0.65	0.46	0.44	1.64	2.02	1.29	1.91	2.06	2.21	1.32	1.30	0.71	0.99	1.86	1.89	0.65
Fe^{++}	5.14	5.99	4.45	4.74	5.66	3.36	4.79	5.00	4.14	4.79	5.22	4.84	4.44	5.31	5.34	5.66	5.47	4.42
Mn	0.13	0.11	0.09	0.08	0.07	0 .11	0.05	0.10	0.09	0.05	0.12	0.09	0.09	0.13	0.10	0.13	0.11	0.09
Mg	12.46	8.38	6.86	6.01	10.67	5.29	9.94	6.73	11.42	9.74	9.78	8.82	4.76	7.89	7.98	10.55	10.97	7.13
Ca	5.50	5.43	6.49	6.02	6.47	6.25	7.28	6.21	7.42	7.40	6.23	6.42	5.46	6.62	5.29	6.37	7.62	5.45
Na	3.82	3.35	4.16	4.44	4.64	3.94	3.70	3.19	2.64	3.66	3.03	3.69	4.76	4.91	4.28	4.41	2.20	3.09
K	1.10	0.79	0.89	0.84	1.44	0.98	1.24	1.01	0.79	0.85	1.28	0.99	1.21	0.93	0.87	1.21	1.28	0.49
P	0.28	0.31	0.43	0.22	0.23	0.22	0.81	0.26	0.32	0.42	0.46	0.36	0.32	0.51	0.22	0.64	0.44	0.09
Oxygen	95.25	97.69	98.73	95.29	97.69	97.29	99.75	98.01	98.59	99.69	96.98	97.89	98.77	98.35	98.10	96.74	97.73	98.32

1. Olivine-basalt. Lower flow, east end of Greens Beach, Tamar Heads.

2. Olivine-basalt. Upper flow, above road cut, 70 ft. level, Inspection Head, West Tamar.

3. Porphyritic olivine-basalt. West bank of East Arm, above 200 ft. level, 1 mile N.W. of Fourteen Mile Creek, E. Tamar.

4. Coarse olivine-basalt. West bank of East Arm, H.E.C. pylon, 225 ft. level, 1 mile N.W. of Fourteen Mile Creek, East Tamar.

5. Coarse olivine-basalt. Picritic phase, west shore of East Arm, 3/4 mile N.W. of Fourteen Mile Creek, East Tamar.

6. Coarse olivine-basalt. Mesostasis rich-phase, west bank of East Arm, 150 ft. level, 3/4 mile N.W. of Fourteen Mile Creek, East Tamar.

7. Olivine-basalt. Upper West Tamar Highway, 3/4 mile N. of Muddy Creek.

8. Coarse olivine-basalt. Scarp top, above West Tamar Highway, S. of Atkinsons Creek, 1 mile due S. of Rosevears.

9. Olivine-pyroxene-basalt. North Esk, 1½ miles N. of Corra Linn.

10. Olivine-basalt. Quarry, above "Talisker" Farm, Rose Rivulet.

11. Olivine-basalt. 1½ miles S.E. of White Hills.

12. Average alkali olivine-basalt. Tamar Trough (average of analyses 1-11).

13. Pegmatite. In coarse olivine-basalt, plateau, 1½ miles N. of Craigburn, East Tamar.

14. Nepheline-basanite. Fine grained phase, Deviot shore, West Tamar.

15. Nepheline-basanite. Coarse olivine-basalt phase, Deviot shore, West Tamar.

16. Olivine-nephelinite. East Arm Road. - Batman Bridge Rd. Junction, N. of Spring Bay, East Tamar.

17. Limburgite. "Duneiden" Farm, 2 miles E.S.E. of St. Leonards.

18. Tholeiitic olivine-basalt. 7EX Hill, St. Leonards.

Analyses 1, 3-6, 13-15, and 18, by X-ray flourescence, with Na_2O and K_2O by flame photometry, and FeO by titration using the method of Reichen and Fahey (1962): F.L. Sutherland, analyst.

Analyses 7, 10, and 17, mainly by X-ray flourescence, with Na_2O and K_2O by flame photometry: D.I. Groves and G. Sanders, analysts.

Analyses 2, 8, 9, 11 and 16, by Tasmanian Mines Department Laboratories, Launceston: J. Furst, analyst.

*Analysis 1 is defficient and the sum of the determined elements only totals 98.03. A consideration of the petrology of the basalt and of analyses of similar basalts from elsewhere in Tasmania suggests that the defficiency resides in the SiO_2 value and that the true SiO_2 value would probably approximate 46%. The norm recalculated on this basis would show a lesser amount of nepheline.

Table 2. Analyses of Pyroxenes and Spinel from Olivine-pyroxene-basalt, Corra Linn and Blessington.

Analysis.	1. Augite-xenocryst core	2 Augite-xenocryst core	3 Augite-in reaction rim.	4 Augite-new overgrowth.	5 Spinel-xenocryst	6 Clino-pyroxene-peridotite nodule.
SiO_2	48.8	48.8	49.4	48.8	-	52.9
TiO_2	0.6	0.8	0.8	1.3	0.7	0.3
Al_2O_3	9.2	10.2	6.9	6.6	64.9	7.3
Total FeO	5.7	6.4	6.2	6.8	16.4	2.0
MnO	0.4	0.4	0.4	0.4	-	0.2
MgO	17.0	15.0	16.1	14.6	18.4	16.6
CaO	17.9	18.4	19.6	20.2	-	19.0
Na_2O	0.9	1.0	0.4	0.4	-	1.4
K_2O	< 0.01	< 0.01	< 0.03	< 0.01	-	< 0.01
Cr_2O_3	-	-	-	-	0.2	-
Total	100.5	101.0	99.8	99.1	100.6	99.7

Microprobe analyses by courtesy of N. Gray and D.H. Green, Australian National University.

Analyses 1-5 from Corra Linn basalt, analysis 6 from Blessington basalt.

TABLE 3. Stratigraphic Successions, Tamar Trough, showing probable correlations.

LOWER TAMAR.

Dune sands, talus, alluvium.

Disconformity, ferricrete.

Siliceous sands and gravels 250 ft.

Disconformity, laterite(?).

Olivine-basalt 45 ft.

Sands 2 ft.

Disconformity.

Olivine-basalt 210 ft.

Disconformity.

Clays, sands and lignites 287+ ft.

Disconformity

Dolerite basement.

MIDDLE TAMAR.

Talus, alluvium

Disconformity, ferricrete.

Siliceous sands and gravels 150 ft.

Disconformity, laterite(?).

Coarse olivine-basalt 400 ft.

Nepheline basanite(?) 10 ft.

Disconformity, laterite(?).

Olivine-nephelinite 50 ft.

Disconformity (?).

Porphyritic olivine-basalt (?) 10 ft.

Dolerite gravels 50 ft.

Disconformity.

Clays, sands, gravels and lignites 800+ ft.

Disconformity, bauxite.

Dolerite basement.

UPPER TAMAR.

Alluvium, talus, basalt gravel.

Disconformity, ferricrete.

Siliceous sands and gravels 40 ft.

Disconformity, laterite.

Coarse olivine-basalt 500 ft.

Disconformity, laterite (?)

Olivine-basalt 50 ft.

Disconformity

Clays, sands, lignite & gravels 600+ ft.

Disconformity, bauxite.

Dolerite basement

SOUTH TAMAR.

Windblown sands, talus, alluvium.

Disconformity, ferricrete.

Siliceous sands and gravels 30 ft.

Disconformity.

Sands, clays and gravels 100 ft.

Disconformity, laterite.

Coarse olivine-basalt 400 ft.

Basalt tuff(?).

Gravel 4 ft.

Disconformity.

(Olivine-basalt 100 ft.
(Olivine-pyroxene-basalt 15 (ft.

Disconformity.

Dolerite gravels, sands & clays 150 ft.(?)

Disconformity

Scoriaceous olivine-basalt 60 ft.

Clays, sands, gravels & lignites 900+ ft.

Disconformity, bauxite.

Dolerite basement.

Tholeiitic olivine basalt, 30 ft. limburgite, 20 ft. olivine-nephelinite 50 ft.

TABLE 4. Proposed Cainozoic History of the Tamar Trough.

Age		Event
--?--	(1)	Epeirogenic uplift, with tensional faulting and tilting forming the Tamar Trough.
LOWER EOCENE-PALAEOCENE.	(2)	Dissection with bauxitisation of Jurassic dolerite basement, particularly in the vicinity of fault lines.
	(3)	Deposition of non-marine clays, sands, gravels and lignites, with intervals of lateritisation.
--?--	(4)	Dissection of the sediments, cutting valleys to 65+ ft. below present sea-level in the lower Tamar.
UPPER EOCENE	(5)	Eruption of olivine-basalt into the lower Tamar, and possibly the south Tamar.
	(6)	Diversion of Tamar, west through Beaconsfield between West and Badger Head(?).
--?--	(7)	Dissection of basalt and deposition of dolerite gravels, sands and clays, in the lower, middle and south Tamar.
UPPER OLIGOCENE-LOWER OLIGOCENE	(8)	Eruption of olivine-basalt at East Arm, flowing into the lower Tamar.
	(9)	Dissection(?).
	(10)	Eruption of olivine-nephelinite at Spring Bay.
	(11)	Lateritisation of olivine-nephelinite(?).
OLIGOCENE	(12)	Eruption of nepheline-basanite at Deviot and olivine-basalts in the upper and south Tamar.
	(13)	Lateritisation of the olivine-basalt in the upper Tamar(?).
	(14)	Dissection, deepening valleys to below sea-level in the lower to middle Tamar, with deposition of basalt-bearing gravel at Breadalbane(?).
--?--	(15)	Eruption of thick flows of coarse olivine-basalt in the middle, upper and south Tamar.

MIOCENE
UPPER MIOCENE–LOWER MIOCENE

(16) Diversion of Tamar through Longford as the South Esk(?). Re-diversion of the Tamar eastwards at Long Reach through the Tamar Heads(?).

(17) Deposition of sands and gravels on the basalts at high levels, related to marine transgression in Bass Strait(?).

--?--

(18) Dissection, with entrenchment of Tamar, following marine regression in Bass Strait.

PLIOCENE

(19) Lateritisation of valley profile forming the Woodstock surface.

(20) Dissection and deposition of fluviatile beds containing basalt and laterite fragments at Perth.

--?--

QUARTERNARY

(21) Dissection to below present sea-level during Glacials. Drowning of Tamar during Interglacials, with deposition of siliceous sands and gravels, and formation of terraces associated with levels at 200, 100, 70-80, 50 and 25 feet above present sea-level. Development of ferricrete soils. Extensive land slippages forming large talus deposits below basalt cappings.

(22) Deposition of windblown littoral and inland sands. Deposition of sands and gravels associated with a 10 ft. marine-level(?). Deposition of fluviatile alluvium. Land slippages.

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with alkali basalt and tholeiite trends after Murata (1960); (d) $FeO+Fe_2O_3/MgO+FeO+Fe_2O_3$; S (trend of Skaergaard liquid series, Wager 1960); K (Kilauean tholeiitic trend, Tilley 1960, Muir and Tilley 1963); H (Hawaiian alkali basalt trend, McDonald 1949); P (Prospect teschenite trend, Wilshire 1967); C (Circular Head crinanite trend, from analyses of Edwards 1941).

Figure 15. FMA ternary chemical variation diagram of the Tamar lavas: F, total iron as FeO; M, total magnesia as MgO; A, total alkalies as Na_2O+K_2O; S (trend of Skaergaard liquid series, Wager 1960); K (Kilauean tholeiitic trend, Tilley 1960, Muir and Tilley, 1963); H (Hawaiian alkali basalt trend, McDonald 1949); B (Black Jack teschenite trend, Wilkinson 1958); P (Prospect teschenite trend, Wilshire 1967); C (Circular Head crinanite trend, from analyses of Edwards 1941).

Figure 16. Solidification index chemical variation diagrams of the Tamar lavas: S.I. (solidification index, Kuno 1959) v SiO_2, Na_2O, K_2O; S (trend of Skaergaard liquid series, Wager 1960); K (Kilauean tholeiitic trend, Tilley 1960, Muir and Tilley, 1963); H (Hawaiian alkali basalt trend, McDonald, 1949); C (Circular Head crinanite trend, from analyses of Edwards 1941).

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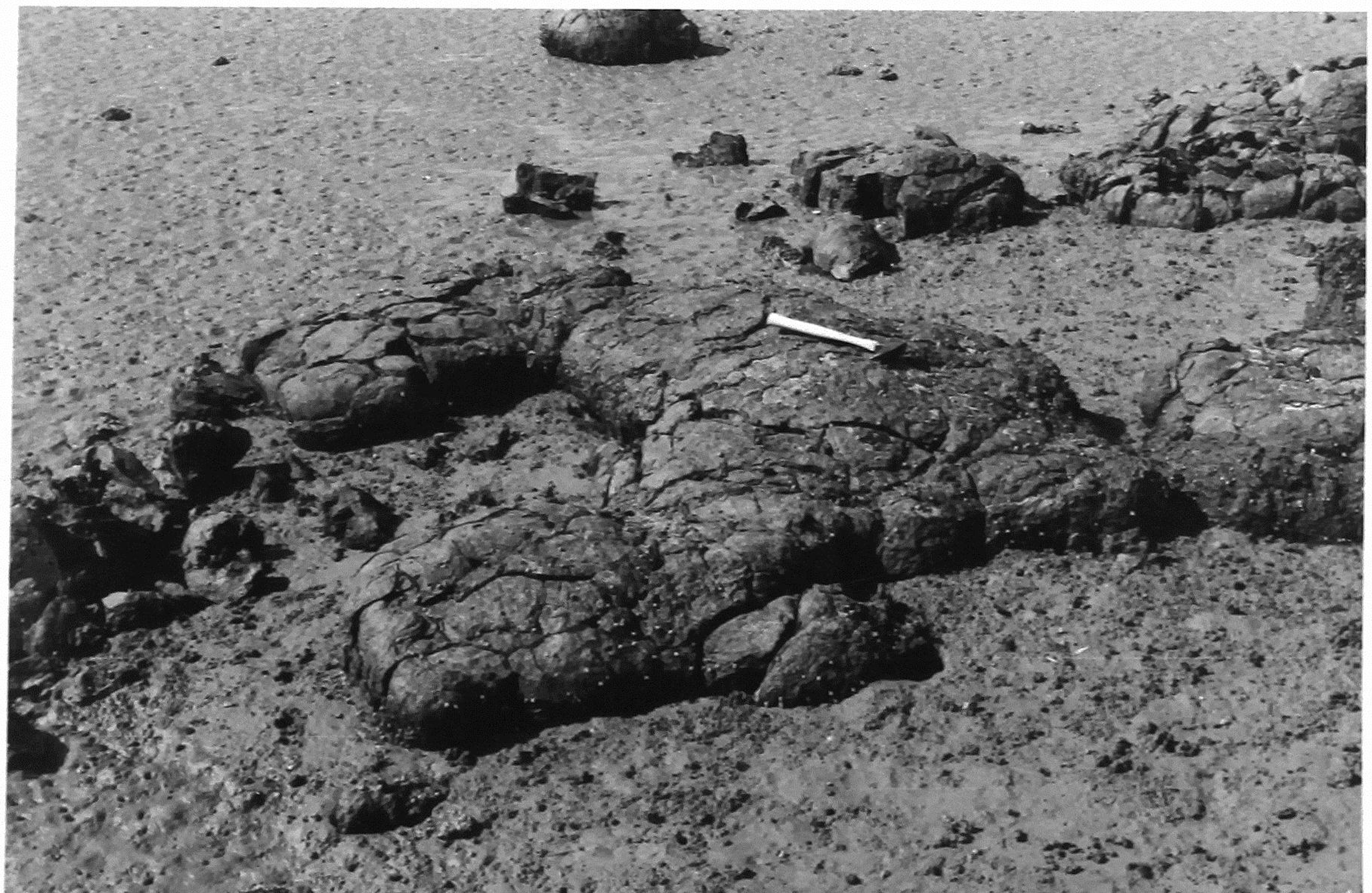

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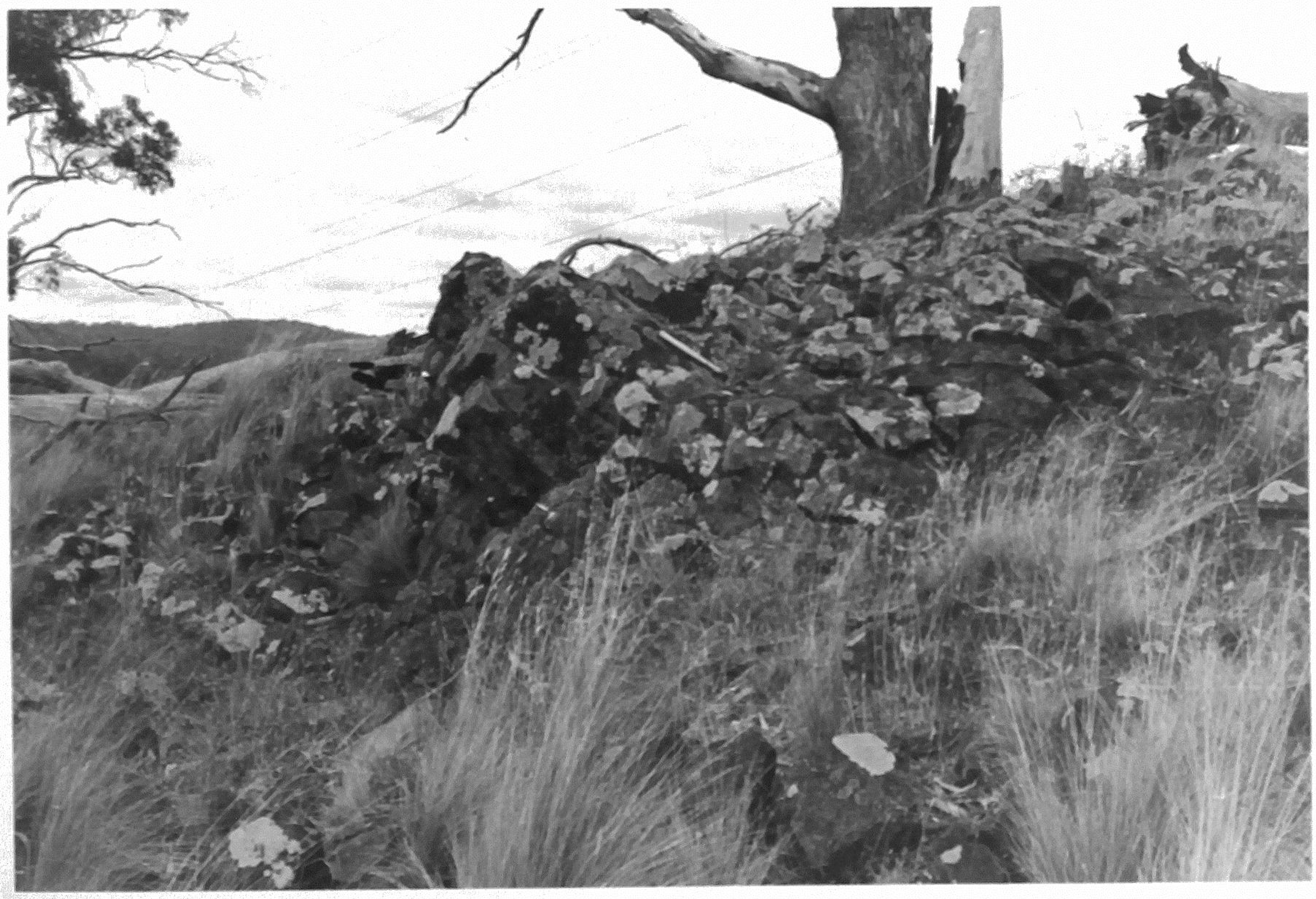

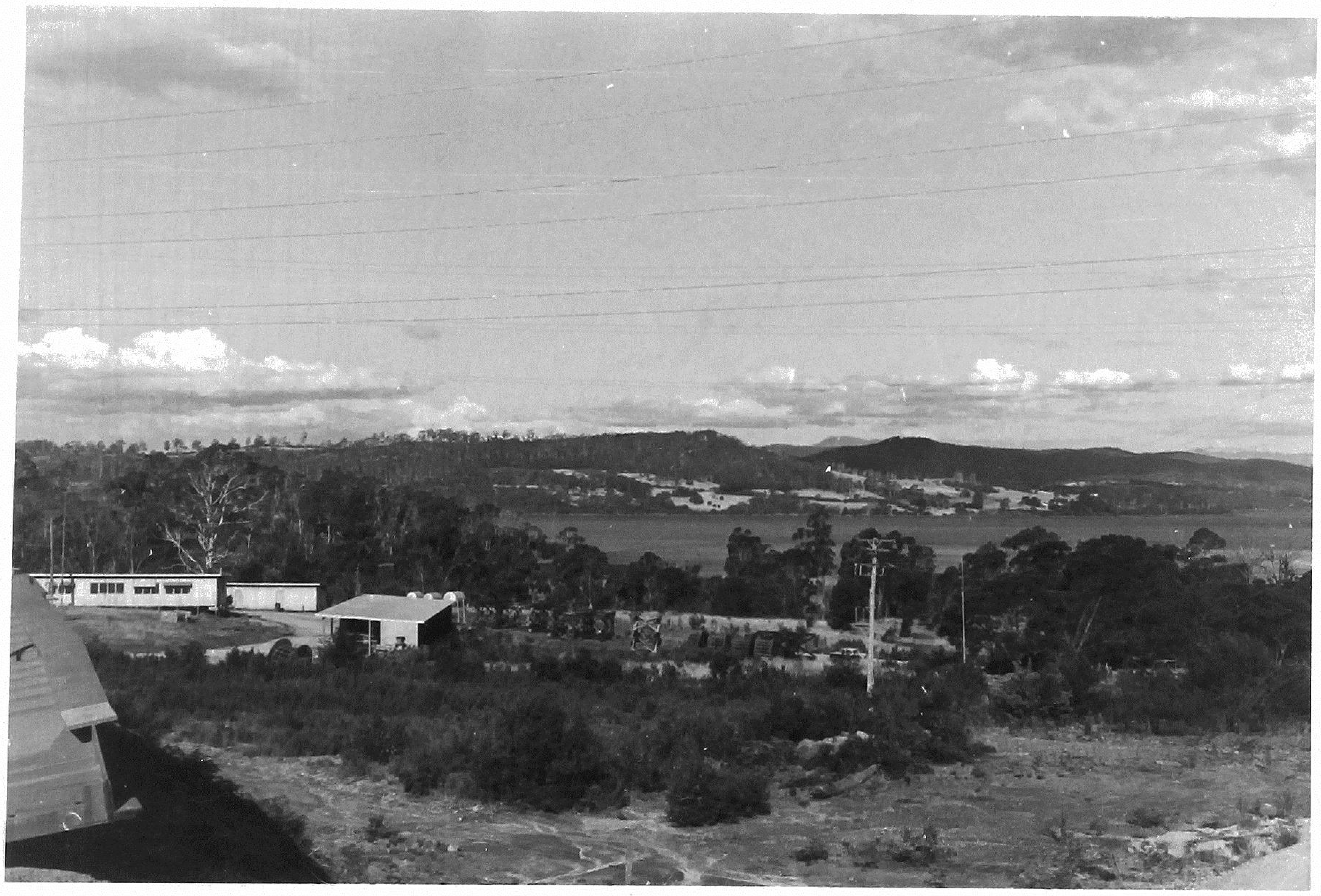

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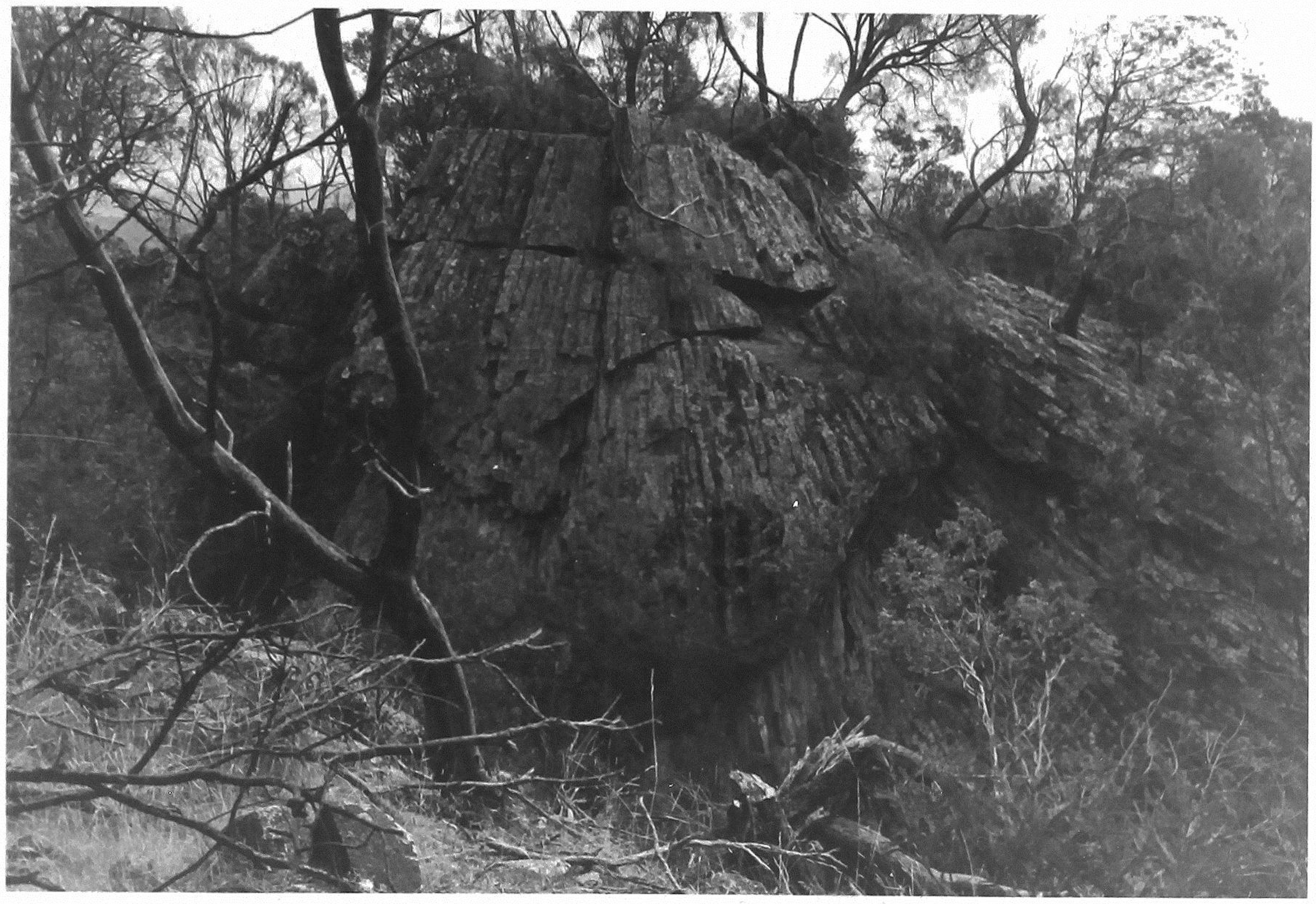

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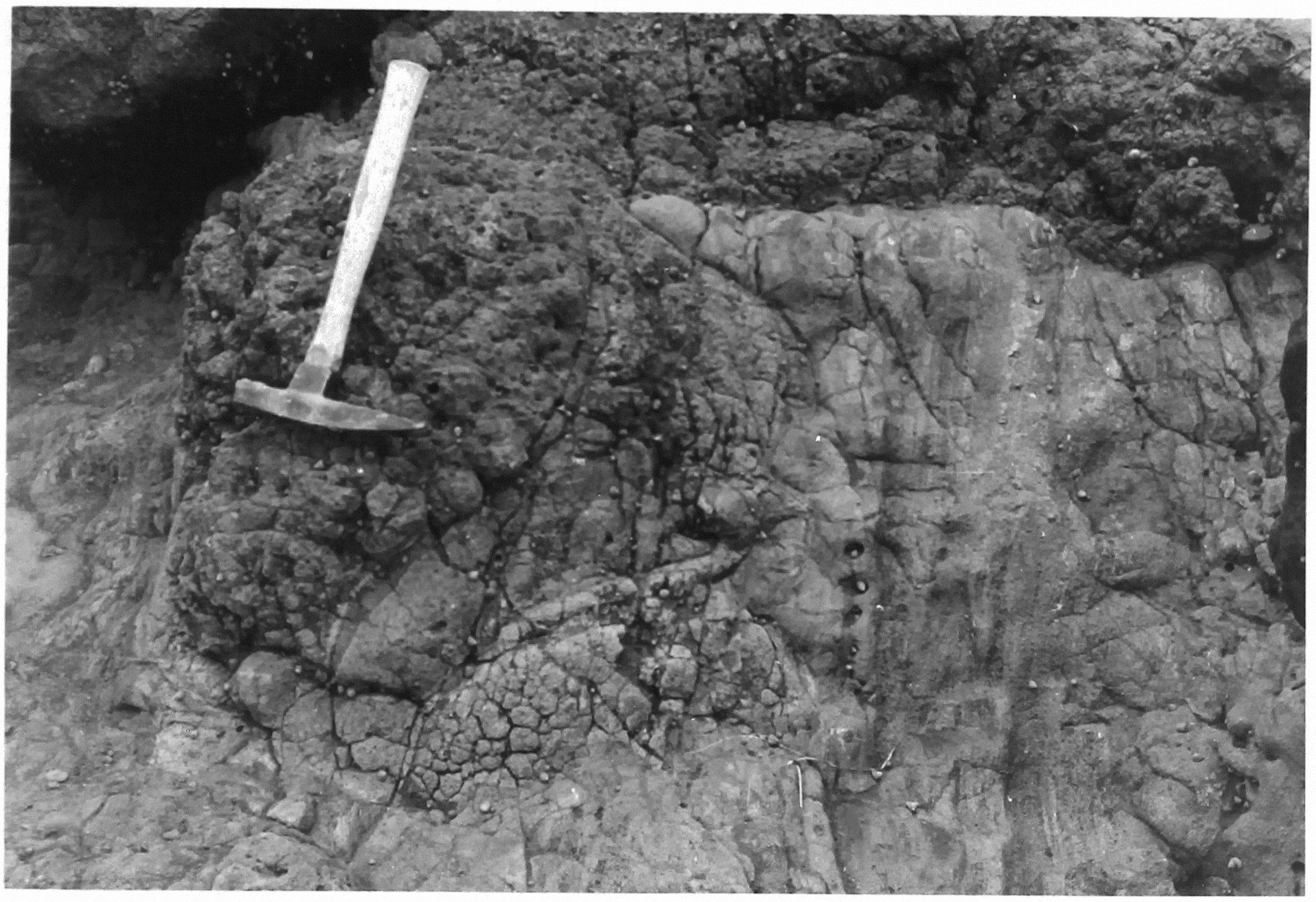

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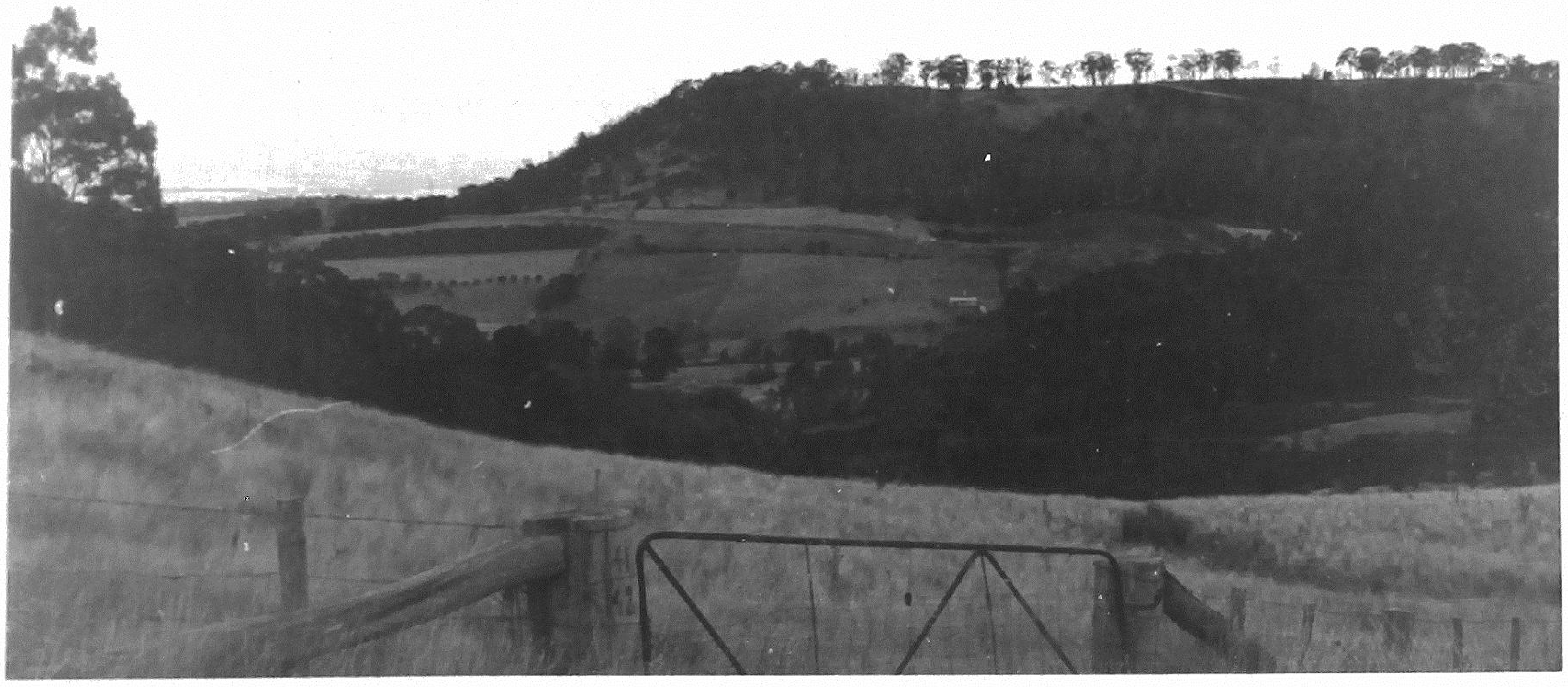

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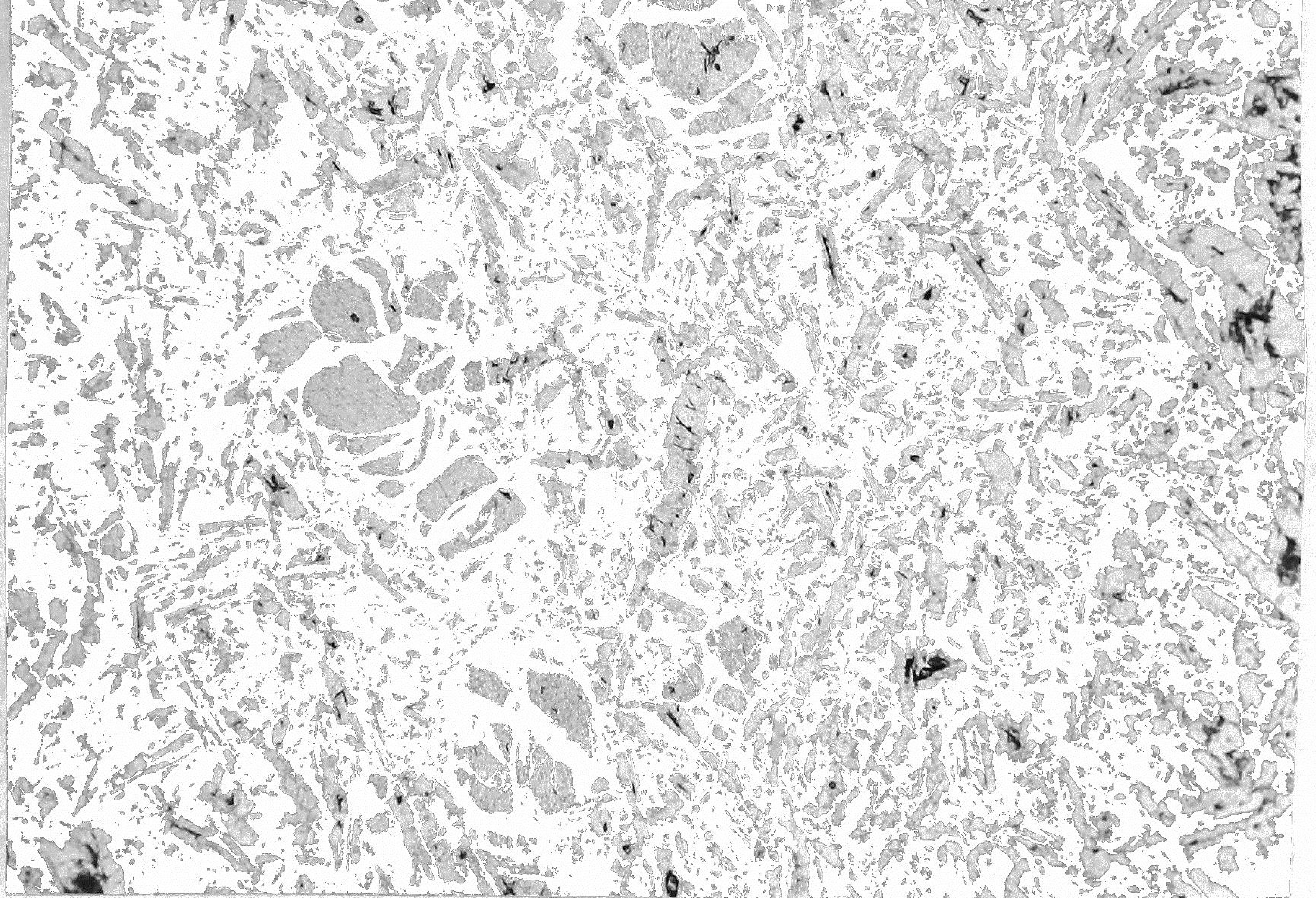

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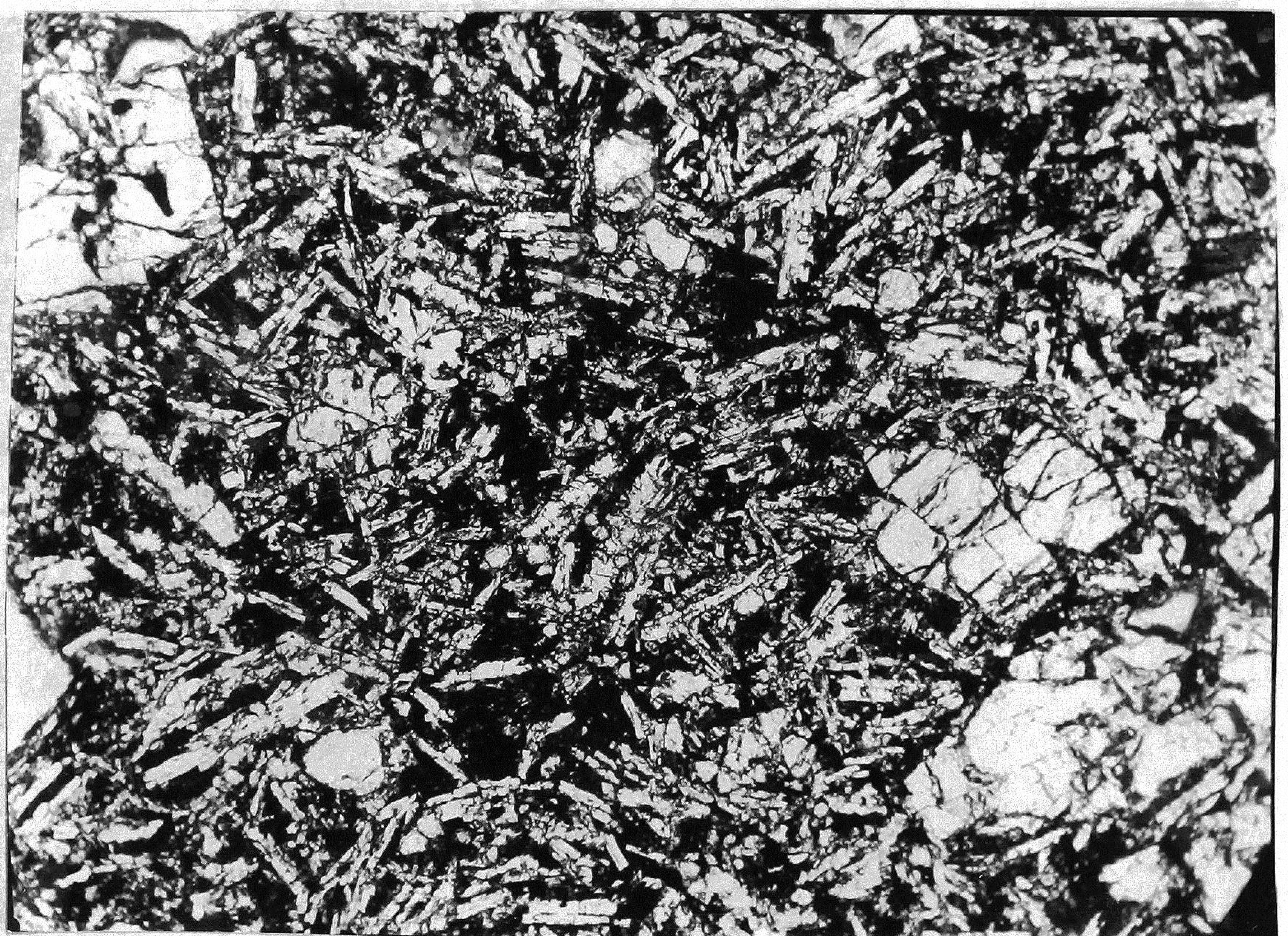

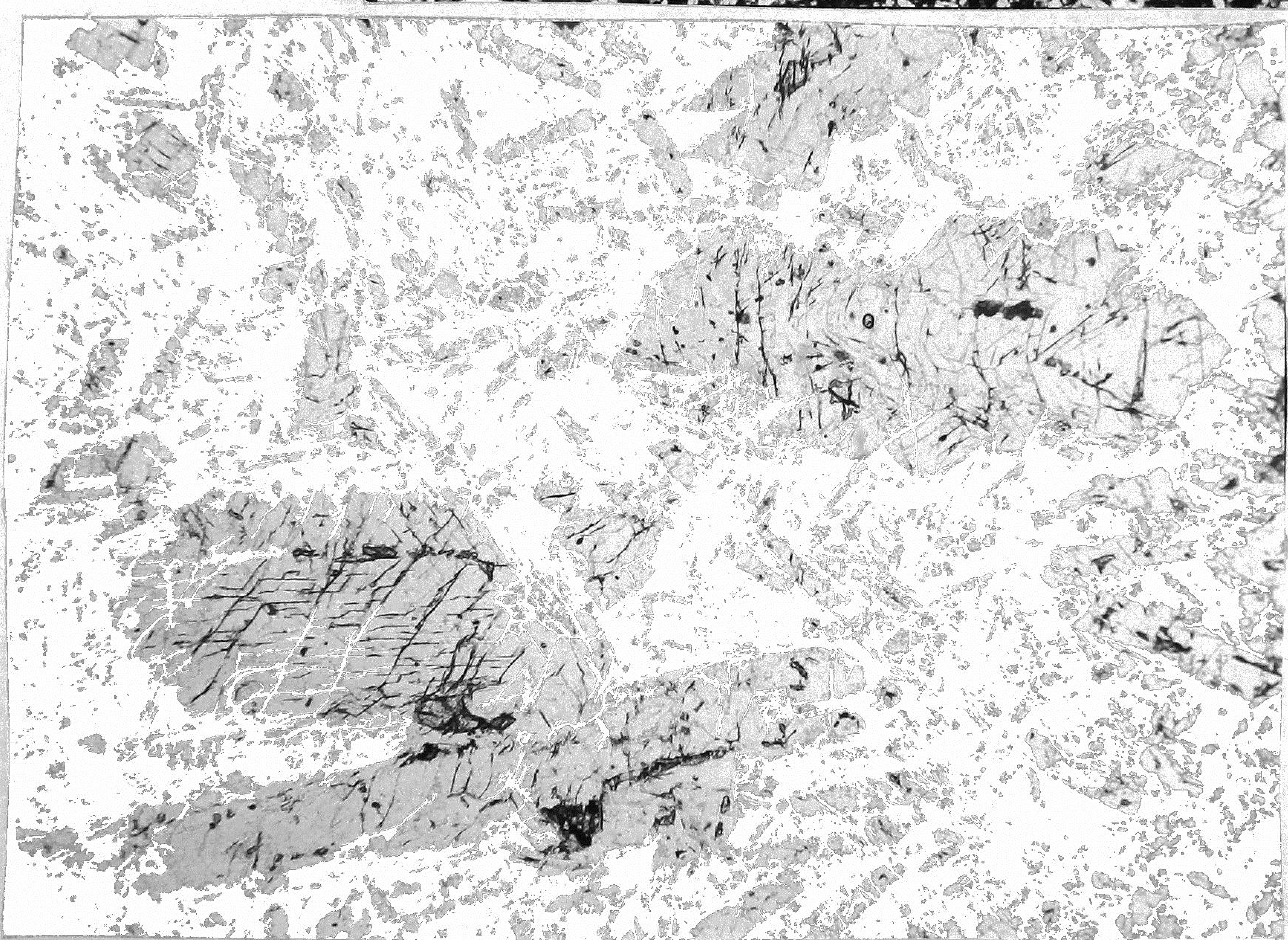

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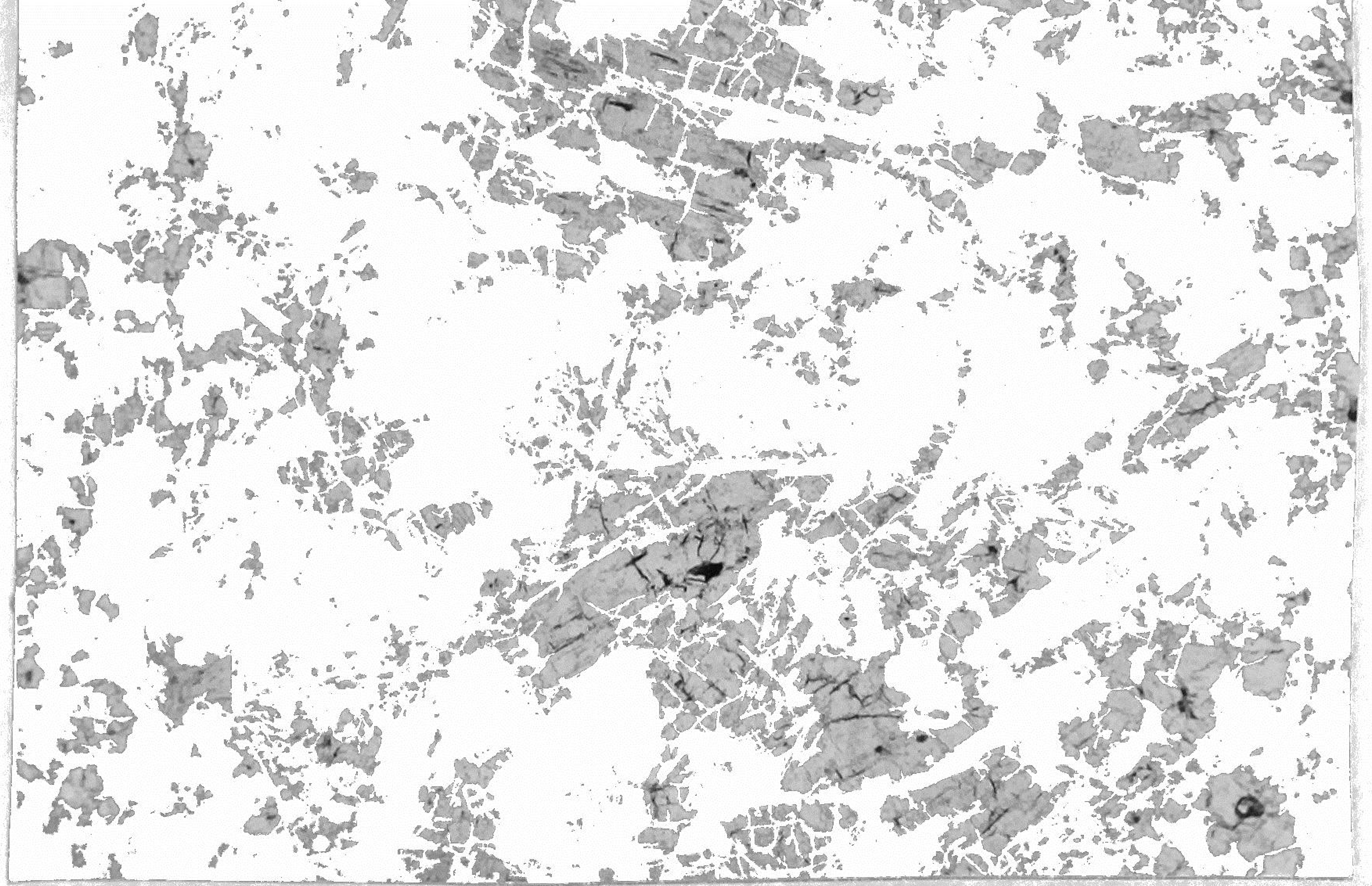

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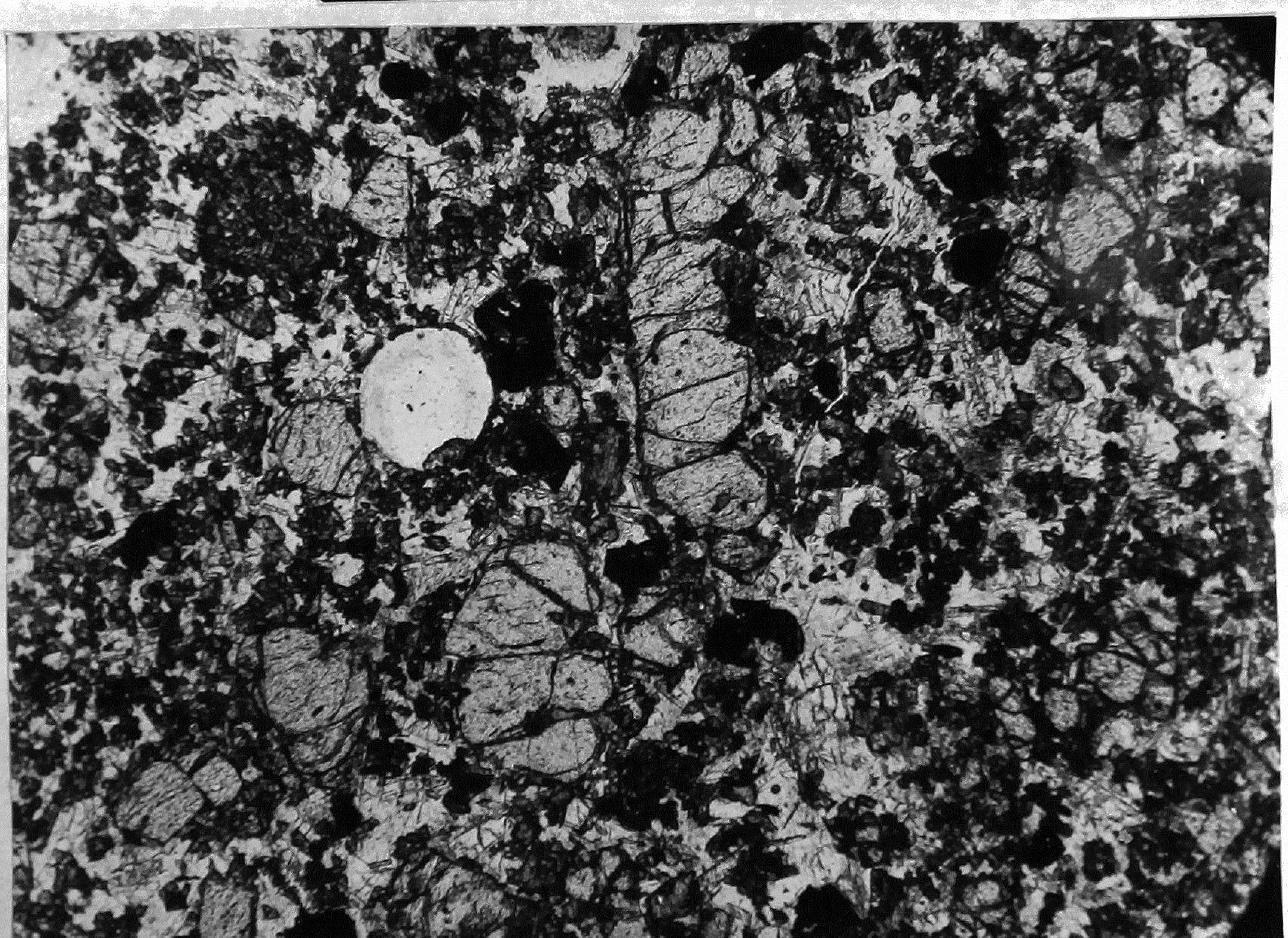

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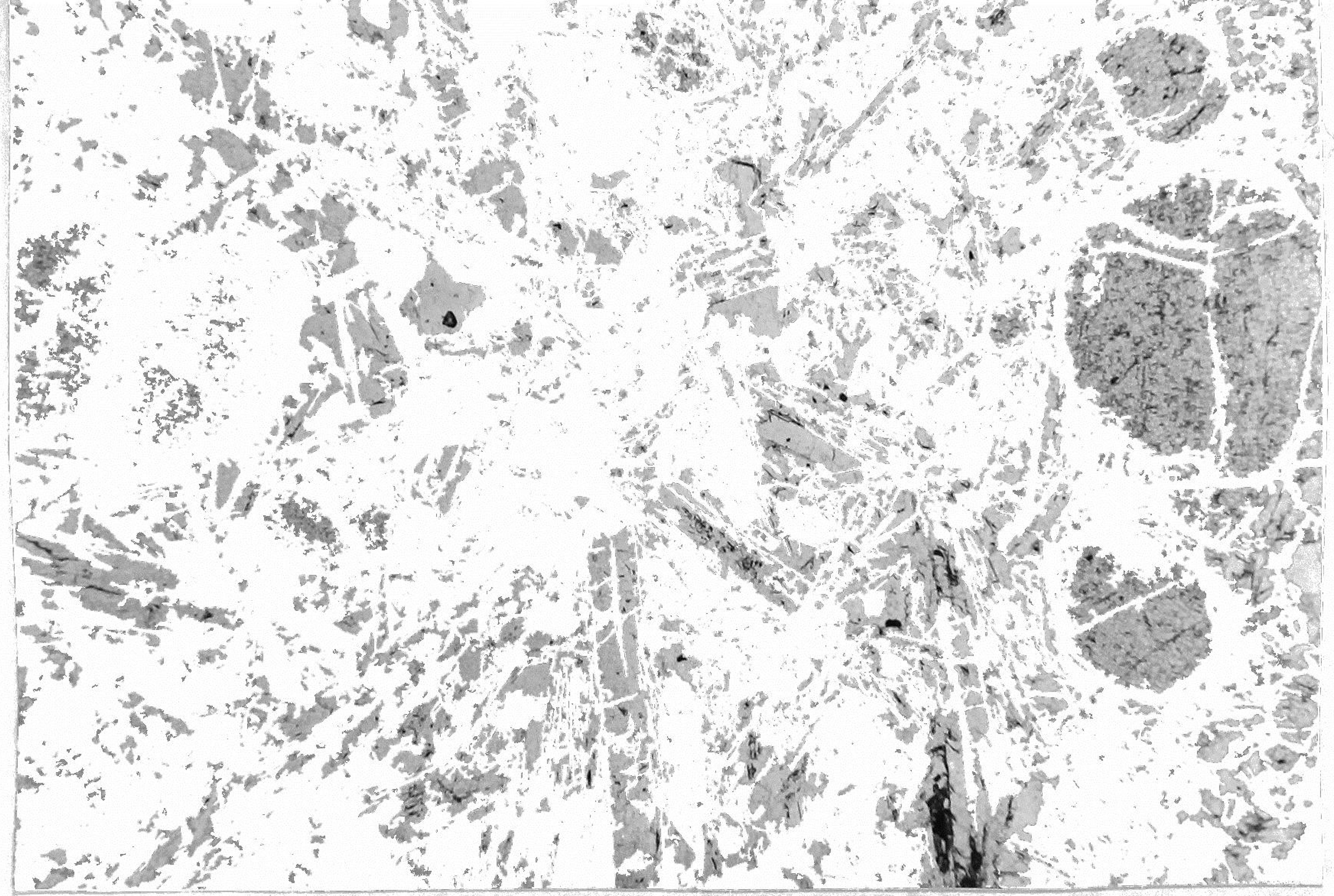

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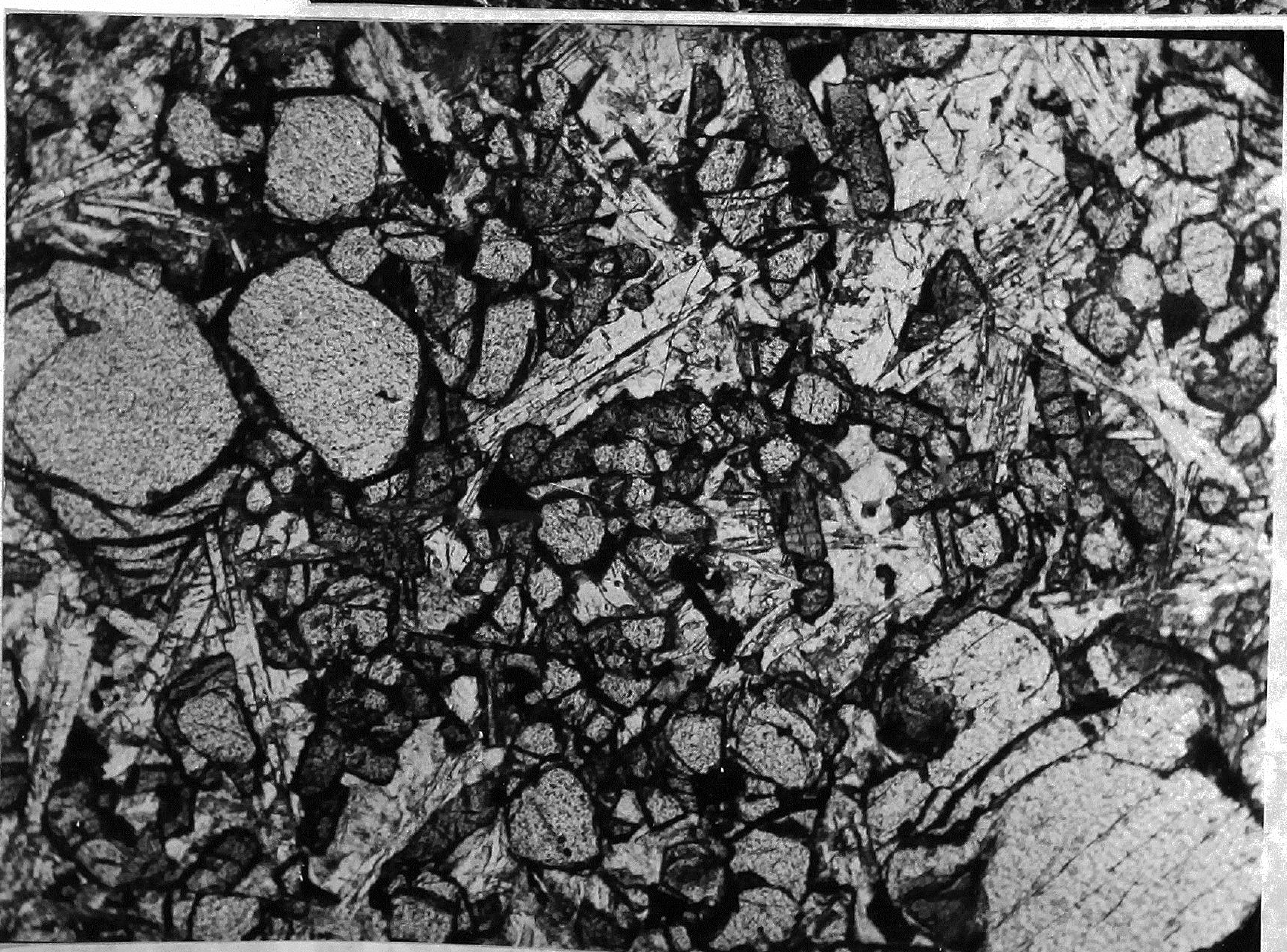

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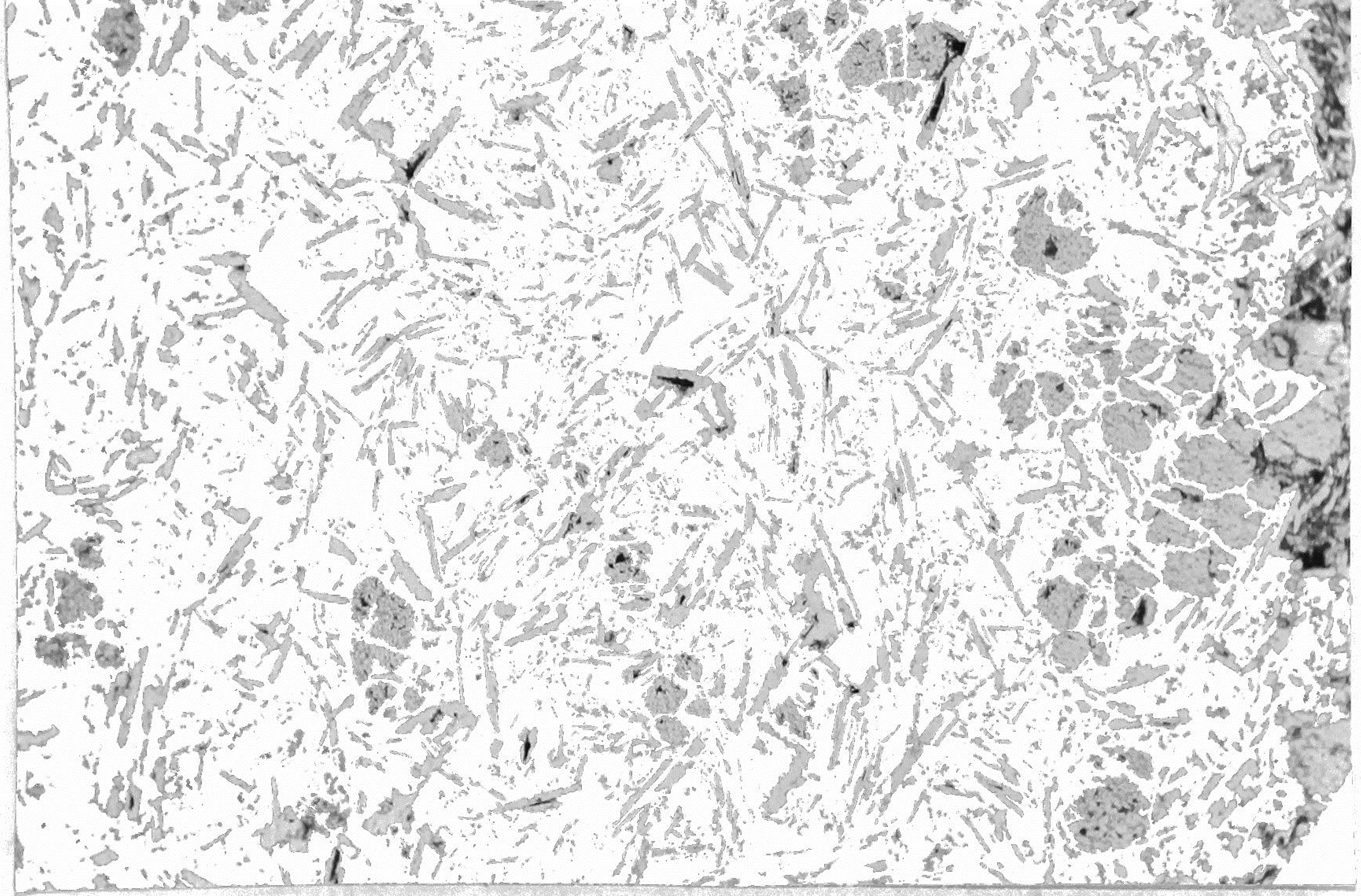

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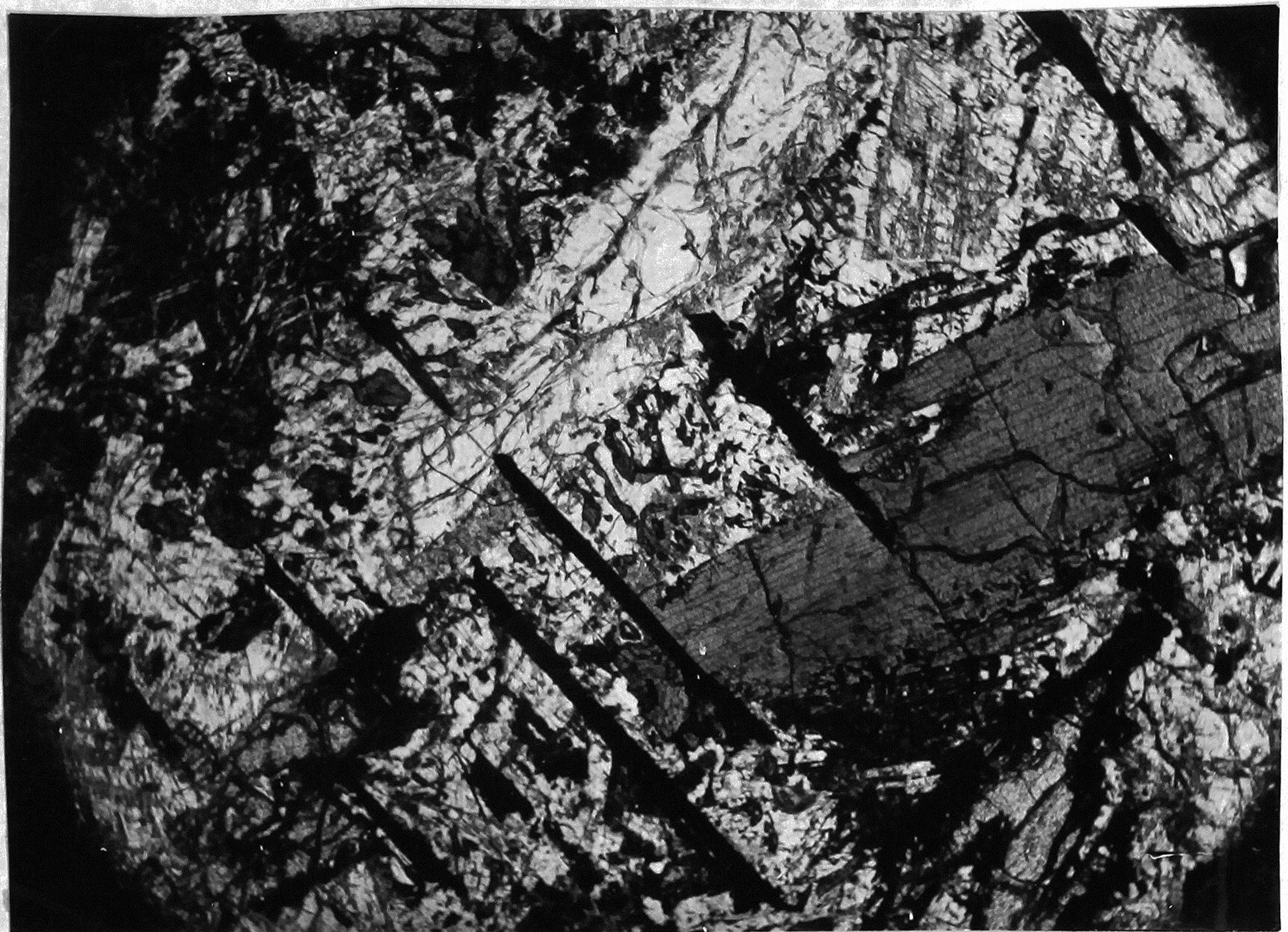

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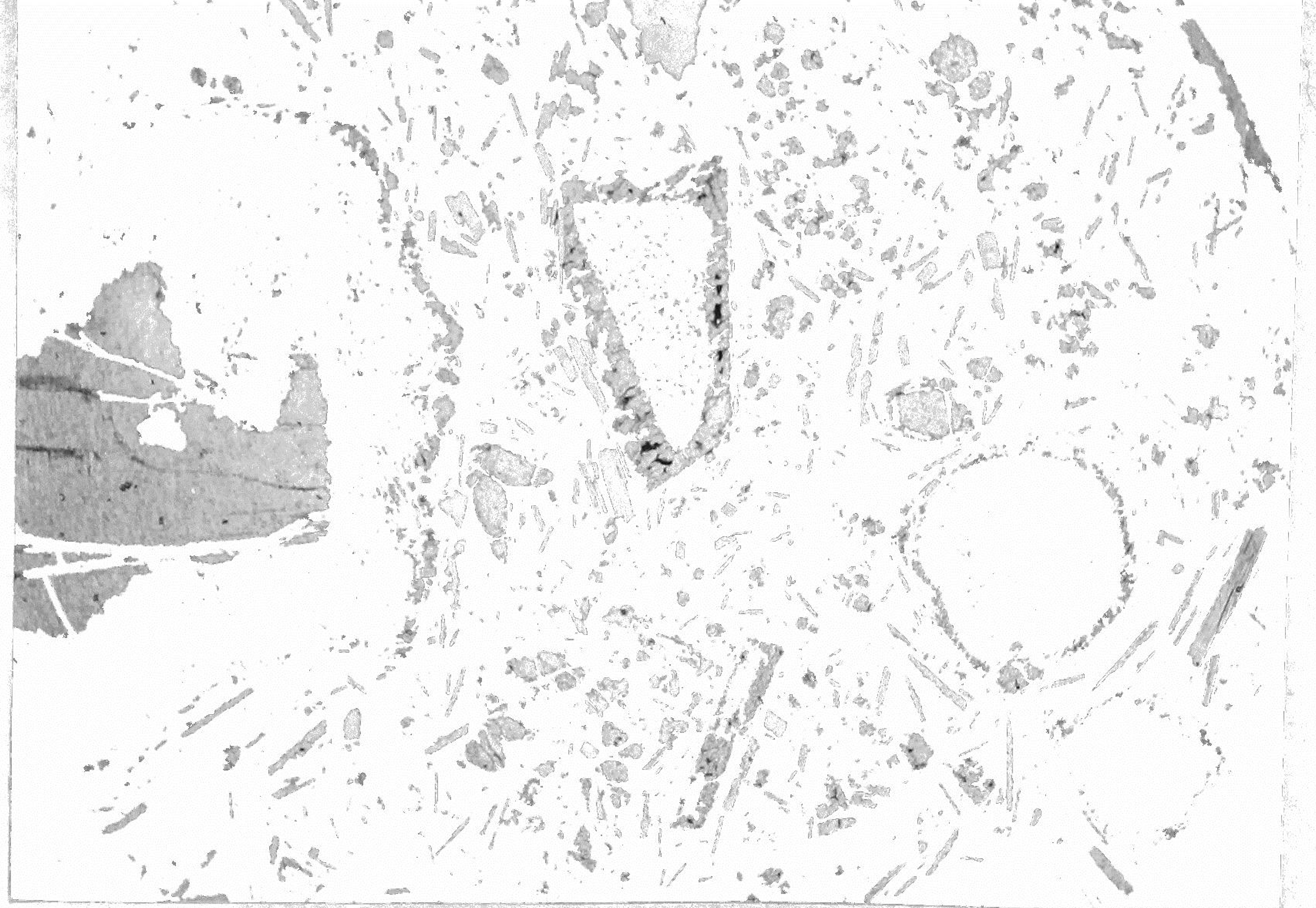

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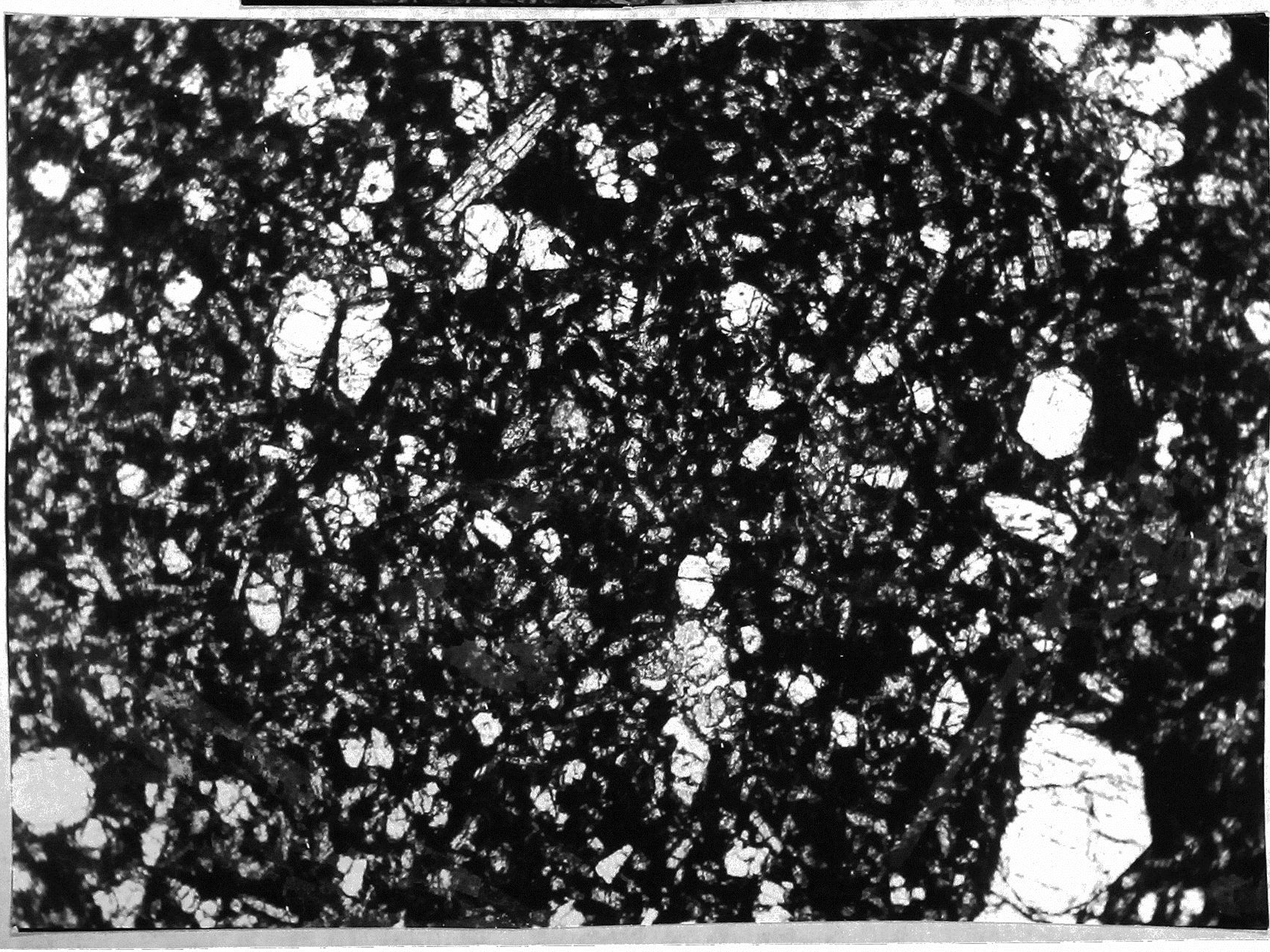

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